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The Canadian Entomologist

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The Canadian Entomologist

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Rearing Houseflies and Roaches for Physiological Research[1]

By R. W. Fisher[2] and F. Jursic[3]

Introduction

The first objective in the breeding of insects for physiological research is a sufficient number of insects of the greatest uniformity both within and between generations. The methods used must emphasize conditions of cleanliness and should preferably give freedom from offensive odours. With the growth of knowledge of the factors involved and with the development of new food materials the rearing procedures have been modified. This article describes the present status of our methods used in the rearing of houseflies and roaches.

Houseflies

The important basic feature of the method for *Musca domestica* L. is the use of milk as the major constituent of the larval medium (Fisher & Morrison, 1949; Fisher, 1952). Originally designed to supply flies for one small research project, the method has since undergone many changes in order to satisfy large scale programs requiring from 5,000 to 20,000 flies daily. It is described in full to take into consideration the most recent techniques.

Breeding Stock

One thousand pupae (about 25 g.) are placed into each stock cage and the emerging adults supplied with a feeding dish of absorbent cotton soaked with diluted whole or evaporated milk, a dry ration (dried brewer's yeast 1 part, whole milk powder 3 parts, sugar 6 parts) and a water fountain (Figure 1). The wooden cage is 12″ x 12″ x 16″ with 20-mesh saran plastic screen sides and top, and a sliding door guided by aluminum moulding. The door has a circular hole 5″ in diameter and a wooden ring grooved on the outer edge to hold an elastic binding on a cotton sleeve. The wood is waterproofed with several coats of varnish.

A battery of eight cages is used. Daily one lot of pupae ready to emerge is added to the battery at one end and the seven day old adult stock removed from the other end. The old flies are killed with a hot water spray and the cage cleaned. Flies begin to lay at four days of age and so eggs are obtained from the last four cages. For the preparation of the oviposition dishes, two wads of absorbent cotton are saturated with milk and folded in a petri dish so as to leave a cleft (Figure 2), for the females prefer to oviposit in a crevice. The proper moisture content is obtained by tilting the dish and allowing excess fluid to drain off. Combining eggs from four cages ensures a well mixed and reproducible strain. The eggs are removed from the pads with a stream of water and shaken in a beaker to break up the clumps. Empty shells and infertile eggs float free and are decanted. The good eggs are transferred by means of a dropper pipette to a graduated tube (a 2-inch portion of a 5 ml. graduated pipette) closed on the bottom with bolting silk. The water drains away leaving the eggs in a compact column. This tube is inverted, and the eggs washed out, resuspended in 10 ml. of water and spread evenly over the medium.

Larvae

Larvae are reared in a battery jar, 8½″ in diameter, on a medium consisting

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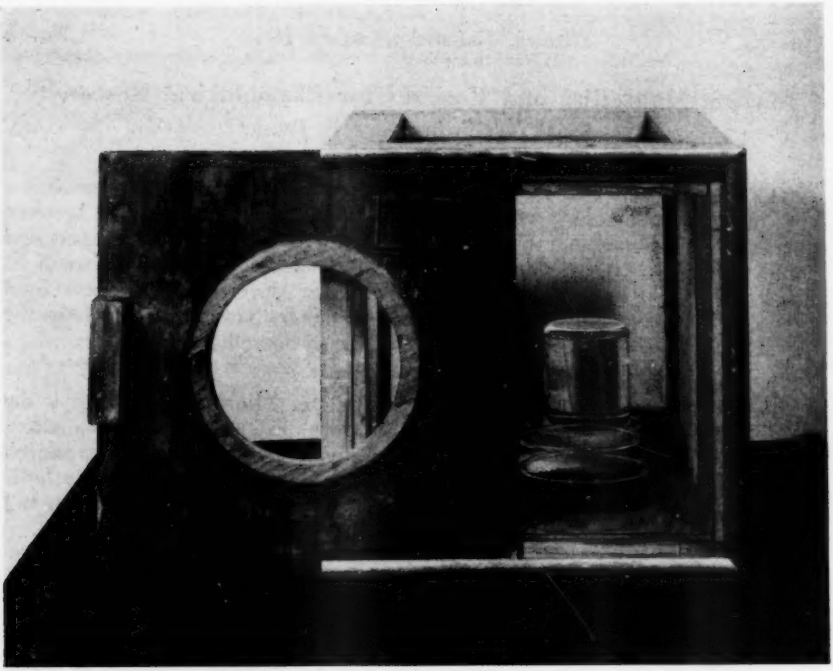

Fig. 1. Stock cage for adult houseflies with puparia feeding dish and water fountain. The cotton sleeve is not shown.

of absorbent Cellucotton[4] 75 g., evaporated milk 540 ml., water 360 ml., dried brewer's yeast 21 g. (Figure 3). As the Cellucotton must be in the proper physical condition to promote the best growth of microorganisms in the milk and an easy passage for larvae, it is minced or shredded into pieces about one inch long by guiding it slowly (2 or 3 layers at a time in the form of a rope) into the blades of a mill (Wiley Mill, Model No. 2, Arthur H. Thomas Co.). There is no wastage as with previous methods where Cellucotton was cut to fit the jar. The Cellucotton is placed in a layer on the bottom of the jar and uniformly wetted with the fluid. The medium is seeded with 0.7 ml. of eggs, and the top of the jar covered with waxed paper fastened with a rubber band or plastic hoop. Several holes (small enough to exclude stray flies) are made in the paper and the culture labelled and placed in a room at 28±1°C and 55-60% R.H. After four days the waxed paper is replaced by a screen cover. The increased ventilation dries the walls of the jar and prevents the larvae from crawling out. At the end of the fifth day when the larvae are fully grown and wandering about in search of a pupation site, sawdust is placed on the medium to a depth of two inches. Cedar sawdust is not used as it has been found unsuitable due to its toxic effect on the larvae.

Pupae

When the puparia have become brown, usually at the seventh day from eggs, they are removed from the sawdust by means of a barley screen with apertures

[4]Trade mark reg. by Canadian Cellucotton Products, Ltd., Toronto, Ontario, an absorbent cellulose product.

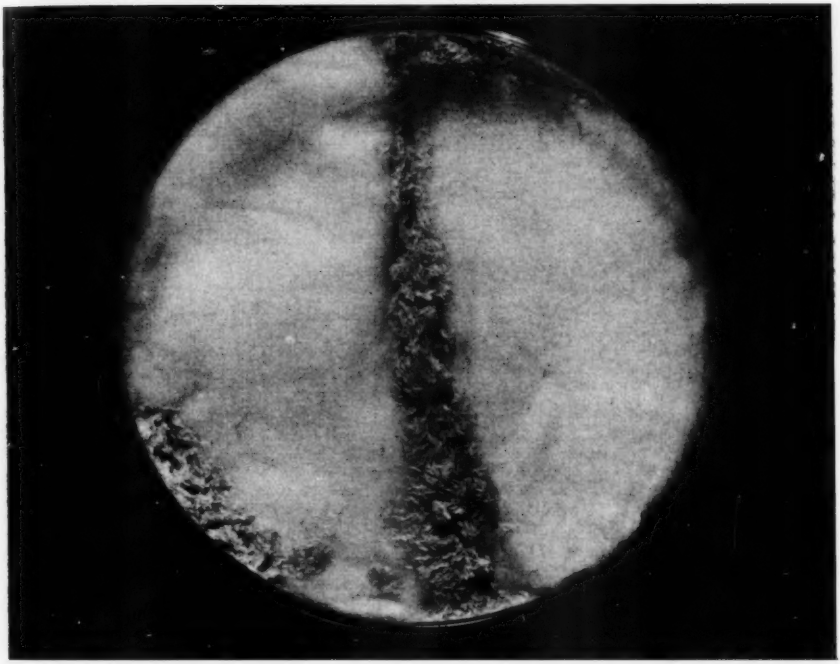

Fig. 2. Oviposition pad in a petri dish showing eggs in the cleft between the pads.

6/64″ in width. Only those on top of the mesh are kept for testing and for stock cages. Other sizes of pupae for special experiments may be separated out by selecting the appropriate screens. Pupae are held in covered petri dishes until they become black, a sign that they are within a few hours of emergence. They are then weighed into dishes for stock cages (Figure 1) and holding cages (Figure 4): 25 g. per stock cage and 15 g. per holding cage.

Test Flies

Holding cages for experimental flies have a stainless steel or aluminum frame 4½″ wide, 5″ deep and 10″ long with top and sides of monel metal screen (Figure 4). A cotton sleeve tapered to fit the top of a pint milk bottle is secured to the cage with a steel collar tightened by a screw at the side. Two circular sliding doors on the bottom permit food and puparia to be introduced and removed without the loss of any flies. Dried whole milk, sugar, and yeast are provided in a 6 cm. petri dish and water in a 6 cm. crystallizing dish with a perforated polyethylene disk 3/16″ thick floating on the surface.

For experimental work, flies are shaken gently into a pint milk bottle held in the tapered cotton sleeve, and are immobilized by CO_2 or chilling.

Continuous Rearing

Any break in the routine rearing schedule, such as occurs at the weekend, seriously interferes with the size and the numbers of pupae produced. Several factors are responsible but the most significant seems to be the extreme variation

Fig. 3. Larval rearing jars showing puparia in sawdust, at left, and larvae tunneling in medium in a younger culture, at right.

Fig. 4. Holding cage for test flies, bottom view, showing dishes of food, water and puparia to be introduced through the circular doors.

in age and development of eggs collected on Sunday. Consequently, an arrangement has been devised as follows: firstly, no cultures are started on Sunday. Consequently, since the time lapse between egg and adult is nine days, there are no flies emerging on Tuesday. Therefore, an additional culture is started on Saturday and development of the pupae therefrom retarded one day by keeping them the last four days before emergence at room temperature, 22°C. These emerge on Tuesday, thus filling the only gap in the continuous supply of adult flies.

Results

Records are kept daily of total weight of pupae, number of pupae per gram and the calculated total number of pupae. Experience has shown that a convenient indication of the production trend is obtained by multiplying the total weight by the total number. This product is plotted daily together with temperature, humidity and modifications of technique, enabling explanations of any anomalous variation to be traced and the error corrected.

The following table indicates the results from a typical culture from one jar:—

Number of eggs (0.7 ml.)	5250 (av.)
Number of pupae	4600 (av.)
Weight of pupae	107 grams
Number of pupae per gram	43
Efficiency	88%
Number of flies per gram of evaporated milk	8.5

American Roach

The American cockroach, *Periplaneta americana* L. is reared in containers of two types: gallon glass jars for very young nymphs and large cages for older nymphs and adults.

Figure 5 illustrates the primary rearing container. This is a one-gallon candy jar with a water fountain fastened to the screened metal screw cap. A corrugated cardboard liner around three sides provides adequate surface for 1500 to 2000 first instar nymphs. Food consisting of Dog Checkers[5], yeast and sugar is placed on a layer of sawdust deep enough to permit the roaches to reach the water fountain.

The roaches are transferred at about the third instar to the secondary container. This is an aluminum box 16″ x 13″ x 10″ with screen sides and Perspex[6] sliding cover (Figure 6). A 250 ml. water fountain is fastened to the outside and has a 9 mm. outlet tube projecting about 3″ into the cage. The tube is sealed at the end and has an opening on the upper side where the roaches can drink. A corrugated cardboard spacer with 24 openings 2¼″ x 2½″ of the type used to protect bottles in cartons is set into the cage with the openings horizontal. It extends 9 inches across the cage and allows a 4-inch space for the drinking tube and a feeding hopper. The feeding hopper is a trough or basket of ¼″ mesh, soldered wire cloth set in a plastic box or tray. The roaches can thus feed on all sides of the Dog Checkers and fine particles of food and faeces drop into the tray. Enough food can thus be provided to last for about two weeks, when the cages require cleaning.

Egg capsules are collected from adult stock cages and placed in a ½″ layer in an Erlenmeyer flask stoppered with cotton. Several flasks are maintained because the eggs vary in age and maturity and so hatch over a prolonged period of time. Newly emerged nymphs are cleared from the flasks at weekly intervals

5Dog food produced by Ralston Purina Co., Woodstock, Ontario.
6A clear acrylic plastic similar to Plexiglas.

Fig. 5. Primary rearing container for roaches with water fountain attached to the screw cap.

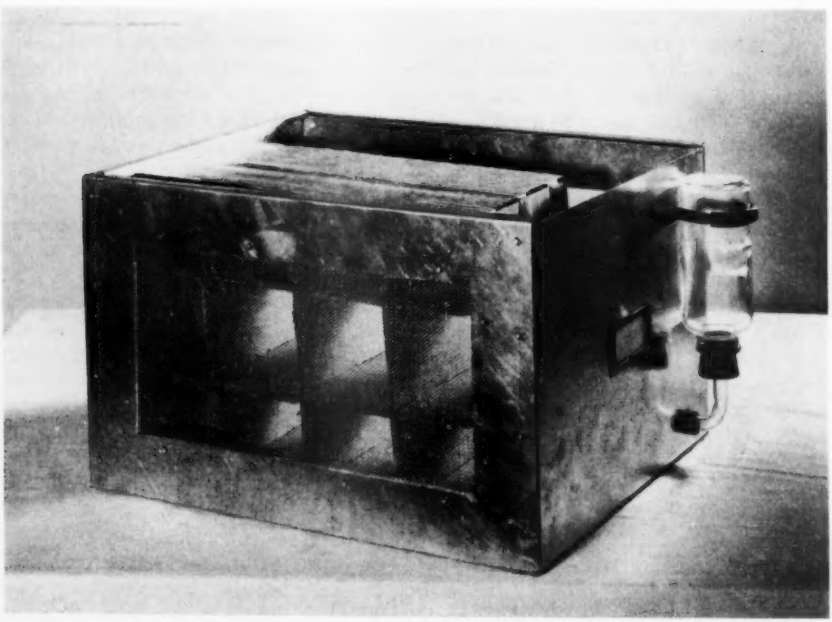

Fig. 6. Secondary rearing container for roaches showing disposition of water fountain and cardboard filler. The plastic top is not illustrated.

or oftener to ensure that each new culture has roaches of approximately the same age. Since they can not cling to glass, the small nymphs are excited by shaking the flask and then poured from the flask into a beaker for weighing. Records are kept of the weights of roaches at different instars or ages and the correct number of roaches for each cage is then calculated by weight. The life cycle of the American roach may vary from four to twelve months under different laboratory temperatures and so each laboratory must make its own records for use in estimating by weight the desired number of roaches per cage. The aluminum cage holds about 1,000 adult roaches and relatively larger numbers of nymphs. With 20 cages it is estimated that about 2,000 adults can be produced per week when operating at full capacity.

At a temperature of 27°C and 60% R.H., the roach culture reaches maturity in about four months. Many thousands of nymphs can be reared to within a month of maturity, and if the demand for adult roaches for experimental work decreases, these nymphs may be destroyed and only a sufficient number kept to provide egg laying adults.

When roaches are to be redistributed they are placed in a room at 0°C for 20-30 minutes. A fan blowing cold air through the cage decreases the immobilization time to 15 minutes. Subsequent handling of roaches is done at 22°C and they are allowed to recover completely before being returned to the rearing room at 28°C. Screens of various meshes are used to separate roaches from excreta and food particles so that they can be weighed and transferred in bulk to new containers.

Acknowledgments

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*R. W. Fisher.

(Received October 16, 1957)

Life-History and Ecology of the Plum Curculio, *Conotrachelus nenuphar* (Hbst.) (Coleoptera: Curculionidae), in the Niagara Peninsula, Ontario[1]

By THOMAS ARMSTRONG[2]
Entomology Laboratory, Vineland Station, Ontario

The plum curculio, *Conotrachelus nenuphar* (Hbst.), always a serious pest of stone fruits in the Niagara Peninsula, Ontario, has increased in importance since 1946, especially in peach orchards. A five-year study of its life-history, ecology, and control was started in 1950 at Vineland Station. This paper deals with the biological phases of the investigation.

History and Distribution

Despite the importance of the plum curculio, remarkably little information on its life-history in Canada has been published. A native North American insect, it occurs in practically all the areas of Canada east of the Rocky Mountains where deciduous fruits are grown. In 1955, Dr. James Marshall (in litt.), Entomology Laboratory, Summerland, B.C., reported that it had not been recorded from British Columbia. In Manitoba, Fletcher (1905) reported that Criddle collected the insect at Aweme in 1904, and it caused considerable damage to plums at Morden in 1954 (MacNay, 1955). In Ontario, Saunders (1871) reported it as a pest of plums 85 years ago, and Gott (1878, 1880) gave accounts of its destructiveness in plums and to a much lesser extent in peach, pear, and apple. At present it is a serious pest on plum, peach, and cherry in Ontario, requiring annual applications of chemicals for its control; control measures are also required in some apple and pear orchards, especially in eastern Ontario. Paradis (1956, 57) has summarized its occurrence in Quebec, where its recurrent attacks have caused very severe damage to apples. The curculio is a very minor pest in the Maritime Provinces, according to Mr. A. D. Pickett (in litt.), Science Service Laboratory, Kentville, N.S., occurring in Nova Scotia mostly in unsprayed plum and cherry orchards and not recognized in apple or peach.

Host Plants and Injury

In the Niagara Peninsula the plum curculio is a major enemy of many fruits, attacking apricot, nectarine, plum, peach, sweet and sour cherries, apple, pear, and gooseberry. Apricots and nectarines are the favoured hosts although they are not grown to any extent. Pears are often scarred and later deformed by feeding and egg punctures, but the larvae fail to develop in them. Quaintance and Jenne (1912) mentioned records of oviposition in gooseberry. At Vineland, two isolated infestations occurred in 1949 and 1954, on gooseberry, and in the former year a large number of adults were reared from the infested fruit. Injury is found in native plum, *Prunus americana* Marsh., and in plum, cherry, and apple seedlings growing wild along roadsides and in woods, all serving as a continual source of infestation for orchards. Fruits of such ornamental trees and shrubs as *Prunus tomentosa* Thunb., *P. pissardi* Carr., and crab, *Malus* spp., are also attacked. Slingerland and Crosby (1914, pp. 243-251) regarded hawthorn, *Crataegus* spp., as one of the original hosts, but examination of the hawthorns in the Niagara Peninsula has not revealed any infestation.

Adults

Emergence.—Adults, emerging from mid July to September from pupae in the ground, overwinter and re-appear the following spring. To determine the

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TABLE I
Number of Overwintered Adults of the Plum Curculio Emerging during Weekly Intervals from Orchard Ground Cages, Vineland Station, 1950 to 1955

Week ending	1950	1951	1952	1953	1954	1955	Total	Average percentage of annual total
Apr. 28	0	103	7	0	0	114	224	4.9
May 5	0	337	6	46	352	146	887	24.3
" 12	10	103	80	71	5	16	285	30.5
" 19	5	132	59	177	194	30	597	43.6
" 26	28	280	320	117	165	82	992	65.3
June 2	220	198	41	28	296	23	806	82.9
" 9	32	66	63	43	192	25	421	92.1
" 16	18	33	21	27	90	11	200	96.5
" 23	15	8	4	2	29	3	61	97.8
" 30	12	2	0	0	7	5	26	98.4
July 7	35	6	0	0	0	2	43	99.3
" 14	30	0	0	0	0	0	30	99.9
" 21	2	0	0	0	0	0	2	100.0
Total	407	1268	601	511	1330	457	4574	

dates of the spring emergence, ten-inch flower-pots covered with wire screen were plunged into the ground in a small orchard and 200 to 350 adults were placed in each, mostly in late September or October after a period of feeding on apple in an insectary. Apples were also provided in the cages. In April the cages were transferred to the insectary for daily examinations.

From 1951 to 1955 emergence began as early as April 22, and continued until late June or early July (Table I). Over 90 per cent emerged by early June, when the young fruits were developed sufficiently for eggs to be deposited in them. In the greatly delayed spring of 1950, very few appeared until after the middle of May, whereas in 1951 and 1955, two early springs, the adults came out in large numbers during the last week of April. Emergence practically ceased when temperatures fell below 55°F.

The time of emergence of adults from pupae in the soil during the summer varied considerably, depending on the type of season. Dates of first emergence of adults in insectary cages ranged from July 12 in 1955 to August 5 in 1950 (Table II). In the early season of 1955, 75 per cent had emerged by August 12; in the late season of 1950, not until September 28. Emergence was completed in all years during October except in 1950, when adults continued to appear until November 16.

During May, before fruits were available, the overwintered curculios fed in the orchards on the new shoots of plum and on the blossom buds of apple; caged adults also readily attacked the tender leaves and twigs of peach. These

TABLE II
Dates on which Various Percentages of Newly Matured Adults of the Plum Curculio Had Emerged from the Soil of Insectary Cages, 1950 to 1955

Percentage	1950	1951	1952	1953	1954	1955
First adult.....	Aug. 5	July 24	July 19	July 20	July 28	July 12
10.....	" 23	Aug. 6	" 25	Aug. 1	Aug. 11	" 22
25.....	" 29	" 11	" 28	" 5	" 18	" 25
50.....	Sept. 8	" 20	Aug. 4	" 10	" 25	" 31
75.....	" 28	Sept. 5	" 16	" 16	Sept. 4	Aug. 12
90.....	Oct. 11	" 19	Sept. 1	" 26	" 13	" 22
100.....	Nov. 16	Oct. 24	Oct. 14	Oct. 22	Oct. 23	Oct. 6
Number observed.	5287	5414	9359	4995	1898	2480

injuries were usually more common on trees nearest the overwintering quarters in the head-lands. This early spring feeding is generally of little importance; when injured apple buds opened, the numerous holes in the petals were conspicuous, but the ovaries were apparently not damaged. Overwintered adults also feed on the young fruits, but most of the external injury to the fruit in the spring is caused by oviposition scars.

Newly matured adults fed on the fruit upon emerging in August and September. In a heavily infested plum orchard in 1955, 10 per cent of the fruits showed feeding areas during the week ending August 2, and 35 per cent by the end of the month. Plums injured by feeding of the curculios during the late summer may ripen and drop prematurely.

Seasonal Abundance.—The seasonal abundance of adults in an unsprayed plum orchard and a peach orchard sprayed only with fungicides was determined from samples collected by holding a portable cloth sheet 40 inches square beneath random selections of branches, which were jarred vigorously with a wooden rod. In 1952 and 1955, 25 jarrings were made per visit; in 1953 and 1954, 30. Three uniformly spaced visits were made every week throughout the season. All of the curculios taken were released immediately in the orchards.

Adults were first jarred from plum and peach on May 8 in 1953, and from plum on May 5 in 1954 and 1955. Peaches were coming into bloom, and Reine Claude plums were almost in full bloom at these times. Of 372 adults jarred in the plum orchard during May, June, and July, 1953, 11 per cent were taken in May, 59 per cent in June, and 30 per cent in July. During July the numbers gradually declined, the low occurring during the week ending July 31, when only nine specimens were jarred from the trees. Immediately the new adults commenced to emerge from the soil the numbers increased markedly, 49 per cent of the 732 collected from July 31 to October 15 in the years 1952 to 1955 being taken between August 7 and 14. The numbers taken declined appreciably after the middle of August, though new adults must have been plentiful at this time. Feeding punctures in the fruit increased markedly in August, but decreased noticeably as the adults left the trees in September. During September the dropped fruit and the ground in the immediate vicinity were examined to find adults. After many hours of searching a very few were seen on the ground near

dropped fruit, and in the crevices of mummied plums. These were probably seeking winter quarters in or near the orchard.

Numbers in the peach orchard generally paralleled those in the plum orchard. None were collected after October 9. Most of the curculios taken from mid September to October 9 were from trees from which the fruit had been harvested.

Longevity.—Adults are long-lived under optimum conditions. Experiments showed that a large percentage of those maturing the previous season survive throughout the next summer. During 1950 and 1951, groups of overwintered adults were kept in glass containers in the insectary and provided with immature apples, which were changed every 48 hours. At the end of the season the survivors were allowed to enter hibernation in screen cages over soil in the orchard. In 1950, 65 per cent of 186 beetles that had matured the previous summer survived to go into hibernation, and in 1951, 63 per cent did so. Thus these adults lived up to 17 months. During 1950 to 1954, none survived the second winter, but in 1955, of 150 specimens that were overwintered for the second winter, two emerged from the ground cage on April 30 and May 21, 1956, having survived for approximately 22 months.

The studies on seasonal abundance in the orchards showed that the longevity of overwintered adults was considerably less than their potential, possibly through predation and also drought, for insectary tests indicated that moisture was needed for maximum survival.

Location and Mortality of Overwintering Adults.—Soil cages made from seven-inch flower-pots plunged into the soil in a small orchard were used to determine the depth at which adults over-wintered. Two series of four cages were provided with different amounts of ground cover: (a) bare soil; (b) half an inch of oat hulls and light straw; (c) one inch of straw; (d) two inches of straw. Two hundred insectary-reared adults previously fed on apples were placed in each cage in September. Apples were also placed on the surface in the cages for food if needed, and remained throughout the winter in a mummied condition.

The cages were lifted in February and March from the orchard and placed in a refrigerator at 36°F., which was low enough to prevent insect activity. After thawing, the contents of each cage were separated into layers and held at 70 to 80°F. until the insects became active.

In the cages with bare soil, 81 per cent of the surviving curculios were at the surface throughout the winter, 16 per cent in the first two inches of soil, and three per cent below the two-inch level. Where the soil surface was covered with varying depths of mulch, 97 per cent of the beetles wintered on the soil surface beneath the mulch, two per cent in the first two inches of soil, and one per cent deeper than two inches. The results from all the cages showed that 93 per cent of 884 surviving curculios passed the winter at the soil surface under mummied apples or other debris; four per cent in the first inch of soil; two per cent in the second inch; and one per cent at deeper levels.

Mortality of overwintering adults was studied from 1952 to 1955 in cages prepared from screen-topped 12-inch flower-pots filled with soil bearing different kinds and amounts of cover and plunged into the soil in the orchard. Reared adults were put into the cages in the fall and a few apples provided as food. In the spring before emergence started the cages were brought into the insectary and the emerging adults removed daily.

The results were not always consistent, but in 1955 they showed that the percentage surviving (42%) was greatest where a layer of small stones covered

the soil, and that bare soil with a few mummied apples was as favourable (30%) as a cover of various types of mulch such as straw, leaves, or chaff (25%). In 1954 where no ground cover except a few mummied apples was present the mortality was 16 per cent, and with a two-inch layer of straw, 29 per cent. The average winter mortality was 70 per cent in 1951, 40 per cent in 1952, 55 per cent in 1953, 45 per cent in 1954, and 70 per cent in 1955.

Copulation and Oviposition.—Repeated copulations were observed during the oviposition periods of a number of females; for example, one pair was observed in copula on June 1, 13, and 29 and July 5, and each of four other pairs on three dates. The number of copulations required to fertilize a female's complement of eggs was not determined.

The progress of oviposition was studied by daily counts of egg scars in an unsprayed, heavily infested plum orchard. Oviposition commenced in late May or early June, as soon as the young fruits began to swell. The first eggs in stone fruits were seen at the time the shucks had split and some had fallen. Oviposition continued at a very rapid rate for approximately three weeks in late May and June, as shown by the following counts in 1954 and 1955:—

Week ending		May 25	June 1	June 8	June 15	June 22	June 29
Percentage	1954	0	2	19	69	84	74
with egg scars	1955	1	31	53	71	57	58

Egg-laying declined considerably after the first of July but some eggs were laid until the early part of August, the last on August 1 in 1952, August 6 in 1953, and August 11 in 1954.

Females were observed laying eggs in apricots and plums in the orchard. In one instance a female that had chosen a slightly roughened spot on a plum took about two minutes to cut a cavity in the exocarp with the mouth parts. Then the beetle turned around, inserted the ovipositor in the cavity, and deposited an egg, taking less than a minute for the operation. Again the insect turned, pushed the egg well into the slit with the beak, and cut the distinctive crescent-shaped crevice in front of the egg site; this act was completed in approximately four minutes. Except for variations in the time of each step, these data agree with the findings of Quaintance and Jenne (1912).

After the plums are about half-grown in late June and early July, the egg scars exude gum which evidently kills many eggs or young larvae. Larvae were obtained from 91 per cent of 2480 Damson plums bearing gum-free egg scars made from June 1 to 14, but from only 37 per cent of 581 plums with gum-filled egg scars made from about June 25 to August 3. Part of the latter mortality may have been due to the presence of some infertile eggs near the end of the oviposition period.

Fecundity.—To determine the fecundity, 25 females were individually caged with males in glass jars in the insectary and provided with young apples in which to deposit their eggs. The apples were replaced every 48 hours throughout the period of egg-laying and kept separately until the larvae matured. The number of viable eggs, as determined by the number of maturing larvae, deposited by a single female varied from 32 to 188 and averaged 75. The largest number deposited in a 48-hour period was 25. Snapp (1930), working in Georgia, reported an average deposition of 59 eggs per female from 185 individuals. Although the writer obtained a higher average per female, the maximum of 516 eggs for one individual in Georgia was almost three times that obtained in Ontario.

In the insectary cages the average duration of the oviposition period was 34 days, the minimum 18, and the maximum 60; the first eggs were laid on June 1

and the last on August 7, most females completing oviposition during the last half of July.

Immature Stages

Incubation.—At mean daily temperatures varying from 66.8° to 74°F. the incubation period ranged from 4 to 7 days with an average of 5.5. In an incubator at a constant temperature of 82°F. the period was slightly less than 3 days.

Larval Development in Fruit.—Infested plums, apricots, peaches, and apples usually drop before the larvae mature, especially when attacked early in the season, although fruit infested in July may remain on the trees throughout the larval feeding period. Infested cherries do not drop but rot on the trees. In 1952 and 1953 infested plums started to drop on June 16, and infested peaches on June 19. The feeding period in plums after they dropped varied from one to 31 days, with an average of 11 days, and in peaches from one to 35 days, with an average of 10 days.

Fruits with more than one larva were often found. In a heavily infested apricot orchard, 13 fruits collected at random from the ground on the day they fell yielded an average of six and a maximum of 13 per fruit. Large collections of infested plums often produced more larvae than the number of fruits. There was no evidence of cannibalism.

As determined by periodic collections of fallen fruit from orchards, larvae from the earliest eggs laid in plum matured from June 14 to 29 (Table III), depending on the type of season. Almost half of the larvae usually matured and left their feeding quarters by early July, or at the latest by July 14. The remainder usually matured by late August, the last on September 12.

In the insectary at temperatures comparable with those in the orchards, the time spent within the fruit, i.e., the combined egg and larval periods, varied from 13 to 49 days, the majority falling within the range 17 to 22 days. The average for over 15,000 larvae throughout the four seasons was slightly longer than 20 days. The few larvae that required over 30 days to reach maturity were exposed to either lower temperatures or unsatisfactory food. Five days being allowed for the incubation period, the larval period in the orchard was approximately 15 days.

The rate of growth of larvae and the number of instars were determined in the following way: Overwintered adults were allowed to oviposit in small green apples in an incubator at 82°F. The fruit in the oviposition cages was changed every 24 hours and held individually in the same incubator. Every day some of the apples were dissected and the larvae preserved for later measurement of the head capsules. From measurement of 97 to 146 larvae per instar, the minimum, maximum, and mean widths of the head capsule of each of the four instars were: first, 0.250, 0.325, and 0.291 mm.; second, 0.425, 0.575, and 0.506 mm.; third, 0.700, 0.900, and 0.780 mm.; fourth, 0.975, 1.200, and 1.096 mm. These figures agree fairly well with those of Hammer (Quaintance and Jenne, 1912), who used a small number of cast capsules.

The eggs required over two and under three days to hatch at 82°F. On the second day after hatching 27 per cent of the larvae were in the second instar; on the third day, 91 per cent. On the fifth day 80 per cent were in the third instar, and on the sixth day 69 per cent were in the fourth instar. From the seventh day after hatching all were in the fourth instar. The average period spent in the fruit from egg-laying to larval maturity was 13.1 days; a few mature larvae left the fruit nine days after the eggs were deposited and others required as long as 24 days.

TABLE III

Dates on which Various Percentages of Larvae of the Plum Curculio had Matured in Orchard-collected Fruits

Percentage	1950	1951		1952		1953		1954	1955
	Plum	Apricot	Plum	Apricot	Plum	Peach	Plum	Plum	Plum
First larva	June 29	June 20	June 28	June 18	June 24	June 24	June 22	June 23	June 14
10	July 5	" 28	July 4	" 26	" 28	" 29	" 29	" 27	" 20
25	" 8	" 30	" 6	" 28	" 30	" 30	July 1	July 2	" 22
50	" 14	July 5	" 11	July 1	July 3	July 4	" 3	" 6	" 29
75	Aug. 8	" 11	" 18	" 6	" 10	" 13	" 7	" 14	July 7
90	" 19	" 19	Aug. 2	" 20	" 24	" 20	" 13	" 29	" 20
100	Sept. 11	Aug. 26	Sept. 8	Aug. 25	Sept. 12	Aug. 9	Sept. 7	Sept. 6	Sept. 12
Number observed	7415	4259	1805	5862	2837	906	5481	2936	3577

TABLE IV

Days from Entry of Mature Larvae of the Plum Curculio into the Soil to Emergency of Adults in Insectary Cages, and Average Temperatures for July to September, 1950–1954

Year	Number reared	Maximum	Minimum	Average	Mean daily temperature °F.
1950.....	5287	84	30	44.6	65.8
1951.....	5413	70	24	37.9	68.3
1952.....	9359	57	21	32.1	70.9
1953.....	4991	75	24	34.8	69.7
1954.....	2210	64	25	37.0	67.7

Development in the Soil.—In the insectary the average time required for mature larvae to develop to the adult stage and emerge from the soil varied from 32 to 45 days, the extremes being 21 and 84 days (Table IV). The time spent in the soil at depths of 0.5 to 2 inches varied indirectly with the mean daily temperatures for July to September, the period when most of the curculios were developing. In 1951, at a mean daily temperature of 62°F. 125 larvae developed to adults in 51 days on the average, and at a mean of 69°F., 54 larvae required 37 days.

More detailed information on the development of mature larvae to adults was secured in the laboratory under controlled conditions. As mature larvae emerged from apples in which they were reared they were put in four-inch pots of soil topped with glass cylinders, where they entered the soil. From 23 to 90 larvae, all emerging on the same day, were put in each pot, which was placed in an incubator at 82°F. At one- or two-day intervals, the contents of one pot were examined, the stages of the insects recorded, and the insects discarded. Figure 1 shows that pupation commenced five days after the larvae entered the soil and was 60 per cent complete after 12 days. The first adults were found in the soil 14 days after the larvae matured, and 83 per cent reached the adult stage after 23 days. The shortest period spent as a pupa was nine days, most of the insects spending 10 to 15 days in this stage. The adults spent seven to 10 days

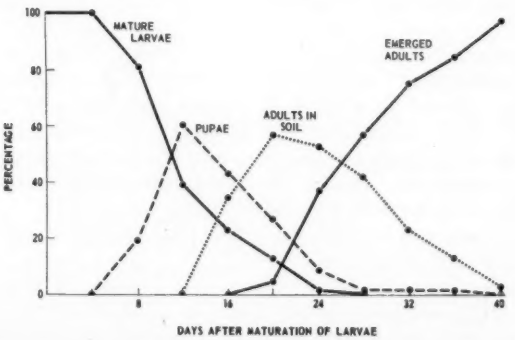

Fig. 1. Development of the plum curculio at 82°F. from maturity of larvae to emergence of adults from the soil.

in the soil, commencing to emerge 20 days after the larvae entered the soil, and continuing to the 40th day.

Effect of Soil Moisture.—The effect of soil moisture on development of the curculio from the time the larvae entered the soil until adults emerged was determined by the following experiments. During 1954 and 1955 mature grubs were placed in flower-pot cages filled with soil, which they immediately entered. The soil used was air-dried in a hot, dry greenhouse for several days before being put in the pots. Certain of the cages were moistened to saturation at certain times. Most of the cages were set up in the insectary, and a few were plunged into the ground in the orchard. Each test was replicated two to four times, and 50 or 100 larvae were placed in each cage.

Larvae introduced into dry soil failed to survive, none reaching the pupal stage. Their shrivelled and discoloured condition within 24 hours showed that they died rapidly. On the other hand, if soil was wet when the larvae entered, up to 82 per cent survived and emerged as adults even though no further moisture was added for as long as 45 days, but when water was withheld for 60 days only 19 per cent survived.

When the soil was moistened every ten days, which appeared to provide optimum conditions, the adults emerged in an average of 35 to 36 days; when the soil was kept continuously wet they emerged in 38 days. Adults did not emerge in the cages where water was withheld for 45 or 60 days as long as the soil remained dry, but most appeared within one or two days after water was added.

This experiment shows that soil moisture is an important factor in the time of emergence of the curculios from their underground cells.

Parasitism

Aliolus curculionis (Fitch) is the most common larval parasite of the plum curculio in the Niagara Peninsula. The adults appear in the orchard in early June, about the time the first curculio eggs are being deposited in the young fruits.

Parasitized curculio larvae are much smaller than normal ones at maturity. The mature parasite larva emerges from the curculio larva after the latter enters the soil, forms a cocoon, and pupates at approximately the same time as the curculio. The adults emerge in 19 to 46 days after the host larvae enter the soil, the average for 598 specimens in 1953 being 24 days, and for 241 in 1954, 26 days. The period spent in the soil is about 11 days shorter than that for the curculio. From 1951 to 1955, emergence of adults began between July 6 and 13 and ended between September 27 and October 17; over 75 per cent had emerged by the end of July.

A small partial second generation in 1953 and 1954 was indicated by the times of adult emergence. In both years first-generation emergence occurred from July 13 to about the third week of August, with the peak during the week ending July 28. Peak emergence of the greatly reduced second brood was evident during the week ending September 8. The second generation could not be large as the number of curculio larvae was decreasing rapidly by the time the first-generation adults of *A. curculionis* were emerging.

The sex ratio favoured the females, 56 per cent females being reared in 1953, 52 per cent in 1954, and 61 per cent in 1955.

How the insect spends the winter is not known. Efforts to keep the summer- and autumn-emerging adults alive in captivity failed, and no adults emerged in the spring from late-developing curculio larvae wintered in soil cages.

In an unsprayed plum orchard the highest percentage parasitism by this species was 26.6 in 1953; the lowest was 7.5 per cent in 1955, and the average for

1951 to 1955 from 9,754 reared grubs was 20. In a peach orchard unsprayed since 1950 the parasitism in 1952 and 1953 was 4.5 and 5 per cent respectively.

A few specimens of *Aliolus rufus* (Riley) were reared in 1951 from larvae from plums at Vineland Station.

Tersilochus conotracheli (Riley) was taken in small numbers every year, the percentage parasitism being 5.7 in 1944, 0.4 in 1952, 2.3 in 1953, and 0.2 in 1955. It was reared from curculio larvae attacking plum and apricot but not from peach.

Cushman (1916) described the life-history of this species, which has one generation a year. Overwintered adults emerged from cocoons in the soil from May 30 to June 28 in 1944, and from June 10 to 22 in 1953. In the latter year curculio larvae parasitized by this species matured from June 24 to July 9.

Other parasites that were reared in very small numbers are *Myophasia* sp., probably *aenea* Wied., and *Cholomyia inaequipes* Bigot, determined respectively by Mr. J. F. McAlpine of the Entomology Division, Ottawa, and Dr. C. W. Sabrosky of the United States National Museum, Washington, D.C.

Summary

The plum curculio has one generation a year in the Niagara Peninsula of Ontario. Overwintered adults emerge from April 12 to early July, depositing eggs from the beginning of June when the young fruits are starting to swell until the first few days of August. Under optimum conditions adults are long-lived, many living up to 17 months. The oviposition period averages 34 days. The combined egg and larval period averages close to 20 days, and the time required for mature larvae to develop to the adult stage and emerge from the soil varies from 32 to 45 days. Newly matured adults emerge from the soil from July 12 to November 16, and feed for a time before entering hibernation. Larvae fail to survive in dry soil, and adults do not emerge from dried-out soil until moisture is added. Prolonged lack of moisture increases the mortality of adults in the soil. Most adults overwinter at the surface under mulch and other debris; type or depth of ground cover does not affect winter mortality to any extent.

Aliolus curculionis (Fitch) is the most common parasite.

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Role of Woodpeckers in Control of the Codling Moth in Nova Scotia[1]

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The value of woodpeckers in insect control has been recognized by entomologists for many years. Woodpeckers seek out and destroy many of the hidden insect pests of forest, shade and fruit trees and in the stalks or stems of agricultural crops. In forest trees, these birds have been reported destroying buprestid larvae and prepupae (1, 4, 16), cerambycid larvae and pupae (9, 10), and scolytid beetles (11-15, 18).

Farmers receive more immediate benefit from the predatory habits of woodpeckers. Barber (2) and Wilbur, Bryson, and Painter (17) reported that woodpeckers feed on the European corn borer during the winter and spring, removing a considerable percentage from the stems of infested plants. Barber (3) found that in an isolated case the hairy woodpecker attacked the corn earworm in the ears of corn and by removing the larvae before damage occurred probably reduced the injury caused by this pest. Glendenning (8) stated that the hairy woodpecker feeds on the larvae and pupae of the parsnip webworm, *Depressaria heracliana* (L.), in the stems. Besse (6) stated that insectivorous birds have become increasingly important since 1930 in the control of the codling moth, *Carpocapsa pomonella* (L.), and have learned to detect large numbers of the larvae hibernating under trap bands and on trunks and branches. Boyce (7) gave data showing that woodpeckers, *Dryobates* spp., destroyed 67 per cent of codling moth larvae on three trees in 1937-1938, and 95 and 80 per cent on two pairs of trees in 1938-1939. Among the measures mentioned for the control of these various pests was the protection of woodpeckers.

Woodpeckers are very adept in finding codling moth larvae in cocoons under the loose scales of rough bark on tree trunks. Bent (5) cited many reports that woodpeckers find hidden insects by tapping with their beaks and listening for the movement of the insect. This may be true with forest insect pests but is improbable with the codling moth. The author occasionally observed that a woodpecker had pecked a hole through a scale of bark behind which there was no sign of a codling moth larva or its cocoon. Also, woodpeckers had drilled into cocoons that contained dead or diseased larvae. These observations indicated that woodpeckers find codling moth larvae by tapping with the beak and feeling for a certain texture rather than by listening for noise of movement.

This is a report on an experiment designed to show the manner in which woodpeckers seek and find overwintering codling moth larvae, and to show their importance in control of the codling moth in Nova Scotia orchards.

Methods and Materials

To determine the manner in which the woodpeckers find the overwintering larvae of the codling moth an orchard was selected in which both the eastern hairy woodpecker, *Dryobates villosus villosus* (Linnaeus), and the northern downy woodpecker, *Dryobates pubescens medianus* (Swainson), were known to be working. Two series of corrugated cardboard strips containing various substances were fastened to the trunks or larger branches of apple trees in this study orchard. The northern end of the orchard had a heavy infestation

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of the codling moth which gradually lessened to a light infestation in the southern end. The bands were distributed at random throughout the orchard.

The first series of cardboard strips, approximately one inch wide and 9 to 18 inches long, contained the following in varying numbers: codling moth larvae in cocoons; cylinders of paraffin wax approximately half an inch long and 3/16 inches in diameter; beef suet of the same dimensions; Number 2 gelatin pharmaceutical capsules containing live insects or spiders; empty Number 2 capsules; and checks of empty cardboard strips.

The first series was exposed for one month and during that time it was noted that the woodpeckers were withdrawing some of the materials through the ends of the corrugations, the birds first sighting the materials from either end. The second series, therefore, consisted of strips of cardboard cut four inches wide and 13 inches long. They contained, in addition to the materials used in the first series: tightly rolled cotton wool, a few of the rolls being soaked in melted suet; leather; and sponge rubber. All materials were cut to the size of a mature codling moth larva. Some of the bands in the second series each contained a single material, whereas other bands had all of the materials spaced at varying intervals. The second series was exposed for three months. To determine whether colour attracted woodpeckers, some of the checks in the second series were spot-coloured with wax pencils.

Records of predation on overwintering codling moth larvae by woodpeckers were kept for the years 1950-1956. One vertical foot of tree trunk was examined on each of six trees in the orchards studied. The number of orchards examined varied from year to year but where possible the same orchards were revisited each year. Orchards were added as occasion permitted while others were deleted because of removal.

Woodpecker predation is easily distinguishable from that of other birds by the characteristic hole made by the beak when the bark is punctured. The beak of the hairy woodpecker is chisel-shaped, whereas that of the downy woodpecker is more narrowly pointed. Consequently, the hole left during pecking is lens-shaped for the former and diamond-shaped for the latter. Because a woodpecker makes a number of pecks with the beak in drilling a hole through the rough scales of bark there are usually many characteristic beak marks beside the hole whereby the species of woodpecker may be identified.

Results and Discussion

Method of Searching

All except ten of the 60 bands of the first series, and all 44 bands in the second series, were visited by woodpeckers, the greatest number of visits being made to those bands in the part of the orchard more heavily infested with the codling moth. More codling moth larvae were taken than any of the other substances. The bands that contained the larvae or suet were usually heavily attacked during the initial visits of the birds, whereas the bands that contained mostly non-edible materials were usually lightly attacked but received more frequent visits. All bands received taps by the birds in three distinct strengths: a light tap barely distinguishable to the naked eye, a moderate tap that just broke through the layer of paper covering the corrugations, and a heavy tap that pierced or tore the cardboard and exposed the hidden material. Observations of the birds attacking the bands showed that searching was done at random, with either light or moderate taps. On the cardboard bands, which had alternating soft and firm strips, moderate tapping was more common than light tapping. On finding a larva or bit of suet a bird usually searched the band further; on finding non-edible material it usually searched elsewhere.

TABLE I
Average percentages of overwintering larvae of the codling moth taken by woodpeckers per ten square feet of tree trunk, Kentville, N.S., 1950–1956

Year	Number of orchards	Total area sampled sq. ft.	Average number of larvae in September	Average taken by woodpeckers by April 30 %
1949–50	18	248	33	58
1950–51	24	358	29	34
1951–52	53	912	29	59
1952–53	30	495	30	60
1953–54	69	1203	7	43
1954–55	70	1240	5	40
1955–56	64	1149	8	63
Average	47	801	20	52

The birds pecked at the wax pellets persistently, evidently searching for food within them. The gelatin capsules, leather, sponge rubber, and dry cotton wool were not withdrawn entirely from the bands, although the cotton wool that was dipped in suet caused the bird some difficulty in detaching it from its barbed tongue, but it was apparently successful after securing the wool behind a piece of rough bark on the tree trunk.

There was no evidence that colour had value in attracting woodpeckers.

During the four months in which this experiment was conducted the female of the eastern hairy woodpecker was seen 18 times in the study orchard while the male and female of the northern downy woodpecker and the male of the eastern hairy woodpecker were seen nine, seven, and four times respectively. They visited the bands almost daily and were seen at different times from early morning until dusk, and on windy, foggy, misty, and rainy days and in snowstorms. Most of the feeding, however, was done during fine weather.

PREDATION

The bark counts indicated that woodpeckers are an important factor in control of the codling moth in apple orchards in Nova Scotia. Table 1 shows that during 1950 to 1956 woodpeckers destroyed 52 per cent of the codling moth larvae overwintering on the trunks and larger branches. In individual orchards, woodpeckers often took over 90 per cent of the larvae. Counts in the fall of 1956 and in the spring of 1957 showed that 67 per cent of the predation attributed to woodpeckers was done by the hairy woodpecker. This species of woodpecker was responsible also for 66 per cent of the attacks made on the cardboard bands of the second series over a three-month period in the fall of 1956.

The presence of woods in an apple-growing area has a bearing on the amount of predation by woodpeckers. The orchards concerned in Table 1 may be classed as belonging to heavily, lightly, or sparsely wooded areas and during the years 1950 to 1956 the destruction of overwintering larvae by woodpeckers was 64, 49, and 35 per cent respectively. In a survey conducted during the winter and spring of 1956-57, nine resident woodpeckers were found in one

heavily wooded area of approximately three square miles and five in a sparsely wooded area of similar size. Predation by woodpeckers for the years 1950 to 1956 in the orchards in these two areas was respectively 72 and 42 per cent. Obviously woods provide food in greater quantity and variety, and better shelter and nesting sites.

Codling moth larvae parasitized by the braconid *Ascogaster quadridentata* Wesm., the only important parasite of the codling moth in Nova Scotia, are small and pale, and the cocoons they prepare for hibernation are small. The size of the empty cocoon showed whether a larva eaten by a woodpecker was parasitized or not. Only 3 per cent of the larvae taken by woodpeckers for the years 1951 to 1956 were parasitized, whereas 14 per cent of the larvae that escaped were parasitized. Woodpeckers and *A. quadridentata* therefore supplement rather than compete with one another in control of the codling moth in Nova Scotia.

Upon alighting on a tree the woodpecker peers under or taps on the loose scales of bark for signs of codling moth larvae. Searching usually starts on the lower trunk and proceeds upwards over the larger branches. When an area is found in which there is an aggregation of larvae, the woodpecker searches more thoroughly. Tapping is either light or moderate, depending upon the firmness of the bark. Where the bark is firm, light taps apparently suffice to indicate the presence of larvae. On detecting signs of a larva the woodpecker flicks off the loose scales of bark, or chisels through them into the cocoon. When the larva is reached it is withdrawn on the barbs of the horny-tipped tongue.

A male downy woodpecker was watched while it fed on codling moth larvae withdrawn from the fruits. It thrust its beak into the codling moth entry, probed for the larva, and flicked the frass from its beak from time to time. Within a few minutes eight larvae were found in this manner, and consumed.

A female hairy woodpecker was observed for 1½ hours feeding on suet and larvae under the cardboard bands and on the larvae under the bark. She consumed 68 larvae, in addition to several bits of suet and an unknown number of larvae eaten when out of sight of the observer. Numerous other small insects were also consumed. In all, 21 trees were visited and the length of the visit per tree varied from one to 15 minutes.

Summary

The eastern hairy woodpecker and the northern downy woodpecker are both important in control of the codling moth in Nova Scotia. In the years 1950 to 1956 these birds reduced the overwintering larval population on tree trunks by 52 per cent. Woodpeckers find codling moth larvae by sight and touch. Searching is done at random with the woodpecker looking for likely spots for cocoons or locating the exact spot by tapping with the beak. After finding the larva, the woodpecker either flicks the bark off with its chisel-shaped beak and feeds on the exposed larva, or drills a hole through the bark into the cocoon and withdraws the larva with its barbed tongue.

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Life-histories and Habits of the Clover Mite, *Bryobia praetiosa* Koch, and the Brown Mite, *B. arborea* M. & A., in British Columbia (Acarina: Tetranychidae)[1]

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Bryobia praetiosa Koch (1836) was formerly regarded as a complex of closely related species or races similar in morphological characters but varying widely in life-history, host plant specificity, and habits. The authors (30) have recently shown that two species, the clover mite, *B. praetiosa* Koch, and the brown mite, *B. arborea* Morgan and Anderson, can be distinguished in British Columbia on the basis of morphological characters. This paper presents ecological data in support of the morphological evidence.

Review of Literature

Common Names

The common names used for the *B. praetiosa* complex vary with the area and the principal host plants. It is usually called the clover or the brown mite in North America (9, 26, 28, 52) and the gooseberry mite in Europe (40, 57). Other common names are: almond mite, almond red spider, apple stem mite, brown almond mite, bryobia mite, clover spider mite, gooseberry red spider, ivy red spider, red apple mite, red mite, red spider, and spiny gooseberry mite (1, 2, 4, 12, 13, 24, 25, 32, 34, 43, 45, 48, 50).

Distribution and Hosts

These mites are of economic importance in many countries. They occur mainly between 20 and 60 degrees in both north and south latitudes (40). A report (11) from the tropics (Colombia) appears to be based on a misidentification as it mentions that the mites form dense webs; particularly in dry seasons. *B. praetiosa* is a non-webspinning tetranychid (2, 7, 26, 39, 46, 52).

The mites have been recorded from low-growing herbaceous plants and from deciduous and coniferous trees. The recorded host plants are: alfalfa, almond, apple, apricot, arbor vitae, barley, beans, blackberry, buckwheat, burdock, burr clover, cantaloupe, cedar, cherry, citrus, clover, currant, dandelion, elm, Engelmann spruce, flax, gooseberry, grape, grasses, iris, ivy, mallow, moss, mustard, narcissus, nectarine, oats, onion, orchids, pea, peach, pear, plum, poplar, prune, quince, raspberry, sand cherry, shepherd's-purse, strawberry, sugar cane, sweet pea, sycamore, tomato, violet, walnut, wheat, wild oat, and zinnia (8, 17, 24, 25, 28, 34, 35, 37, 39-42, 47, 49, 51, 52, 56).

Von Hanstein (40) considered that *B. praetiosa* originally lived on mosses and other low-growing plants and became adapted to gooseberry. It was not mentioned in the literature as a pest on gooseberry until 1890 (1). In Europe its most important hosts are ivy, *Hedera* spp.; gooseberry, *Ribes* spp.; pome fruits; and low-growing herbaceous plants such as legumes and various species of grasses. In most parts of Europe it is considered chiefly a pest of ivy and gooseberry, yet in other parts of the world it is seldom recorded from these hosts. In Australasia it is reported chiefly on fruit trees and to a lesser extent on legumes and grasses. Host plant preference in North America varies considerably in different areas. In the central and eastern United States *praetiosa* is primarily a pest on clover and grasses; in the south and southwest it is common in orchard trees and is an import-

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ant pest of almonds. In the Pacific northwest and Canada it is an economic pest mainly of fruit trees, but is often found on low-growing herbaceous plants such as clovers, grasses, dandelions, and ornamental flowers. Distribution records from South America, Africa, and Asia are scanty and do not indicate host preference.

B. praetiosa has been classed as a household pest on numerous occasions because it sometimes moves in enormous numbers into dwellings during the spring or fall. This phenomenon has attracted attention only in North America and Europe (9, 12, 14, 18, 22, 28, 34, 37, 38, 42, 51, 57). In some parts of the United States and Canada it is considered more important as a household nuisance than as a plant pest.

Life-history and Habits

The life-cycle is typical of tetranychid mites except that the species is entirely parthenogenetic (35). The spherical, red eggs develop into minute, red, hexapod larvae that take on a greenish tinge after feeding. The mite passes through four active and three resting stages: larva, protochrysalis (first quiescent), protonymph, deutochrysalis (second quiescent), deutonymph, teliochrysalis (third quiescent), and adult. During the summer these stages succeed each other at intervals of three to six days and the life-cycle takes more than a month.

The life-history varies considerably in different parts of the world. From one to eight generations per year have been reported (4). It is said to winter in either the egg or the adult stage.

The problem of biotypes has been studied extensively in Europe. Two or more races have been reported by many workers (15, 23, 39, 40, 55, 56). Mathys (23) recognized four biotypes in Switzerland: biotype I feeds only on fruit trees, is multivoltine, and winters in the egg stage; biotype II infests gooseberry, is univoltine, and winters in the egg stage; biotype III is specific to ivy, is multivoltine, and winters in all stages; and biotype IV, which may represent an unresolved complex, feeds on a wide range of herbaceous plants, is either univoltine or multivoltine, and winters in all stages.

In Australia the mite has seldom been noticed infesting herbaceous plants and has never been recorded as a household pest (12). The mite completes two to three generations in the summer. It winters in the egg stage; the eggs are deposited as compact masses on fruit spurs, limbs, and bark (2, 46). Froggatt (12) reported eggs laid in masses on stones and wood on the ground near trees, but his illustrations and descriptions suggest that he was describing winter eggs of *Petrobia latens* (Müller). Although only one race has been reported in the Australian literature, Mr. L. W. Miller (personal communication), Chief Entomologist for Tasmania, has observed overwintering adults on the Australian mainland, indicating that two races may occur there.

The biology of the complex has not been studied in detail in North America, but many workers have noted that it occurs on a wide range of herbaceous plants and deciduous trees. It is reported to winter in both the egg and the adult stage. The number of generations varies from one to five (19, 49). The mite was first noted in the United States in 1878 (51) and was described in 1885 by H. Garman (37) as a new species, *B. pratensis* (=*B. praetiosa*). In 1886, Garman (37) reported that "still another *Bryobia* damages the plum trees in the Pacific coast region". However, Riley and Marlatt (37) could not find any character to distinguish the mites obtained in California, Oregon, and Montana from those collected in the central and eastern United States. Since then, mites that show racial differences have been observed not only in different localities but also on

different hosts in the same locality (43). The *B. praetiosa* complex in the United States still remains unresolved (35).

Venables' (49) observations suggested that two races occur in Canada. He reported that the race infesting grasses and other low-growing herbaceous plants in the Okanagan Valley of British Columbia produced a single generation annually whereas the race that is apparently restricted to deciduous trees had several generations per year.

The mite first became an economic problem for Okanagan Valley orchardists in 1950. About the same time, complaints of infestations in houses first became common; these mites were more difficult to control than those in orchards. Coupled with Venables' observations, this indicated that two races occurred in the area. Also, larvae were found on the cover crops at the bases of orchard trees a few weeks earlier than in the aerial parts of trees. On the cover crops, the mite wintered in both the egg and the adult stages and these winter adults did not migrate to the aerial parts of the trees.

General Methods

Most of the work was done in the Okanagan Valley from 1952 to 1955. That work was supplemented by observations at the University of British Columbia, Vancouver, in 1954 and 1955.

The Okanagan is a semi-arid region. From 1917 to 1948 it had an average annual precipitation of 10.7 inches, an average minimum temperature of -2°F., and an average maximum of 98°F. (33, pp. 6-10). In contrast with this, the respective figures for Vancouver, from 1901 to 1938, were 57.4 inches, 13°F., and 86°F. (3). The weather during the period of investigations was atypical. Beginning about 1948, a cycle of relatively wet and cold weather occurred throughout the province; precipitation was above normal and springs and summers were unusually cool.

Field observations were made mainly in three sites: a lawn at the Summerland laboratory, a commercial orchard at Summerland, and a derelict orchard at Oliver. At first there was a heavy infestation in each site. The lawn was ideal for observations on a "pure culture" of the clover mite, *B. praetiosa*. Ornamental shrubs on the lawn provided sites for oviposition, moulting, and overwintering although the mites did not feed on the foliage. In the orchards, infestations of the mite were common on the cover crops. The trees were infested with the brown mite, *B. arborea* (30). In addition, observations were made on mites found infesting herbaceous plants near dwellings where the clover mite was reported as a household pest.

The life-history of the brown mite was determined by sampling both leaves and twigs of apple trees at weekly intervals from the commencement of winter-egg hatch until the end of September from 1952 to 1955. The mites from both leaves and twigs were removed with a Henderson and McBurnie mite brushing machine (16, 29). Mites on leaves and twigs were removed and counted separately.

Sampling of clover mite populations on the lawn site was started in May, 1954, and continued throughout the summer and fall. In 1955, periodic observations were made from January to May and weekly collections were taken from May to December. Samples during the growing season were obtained by beating the grass and cover crops over a shallow box, and counting therein the number of specimens in each stage. Fall and winter counts were taken from plywood traps in which the overwintering stages congregated (31). The results of the summer and winter counts, together with frequent field observations, provided a general picture of the life-history.

The plywood traps were also used for observations on the overwintering habits of the clover mite. The adults deposited large numbers of eggs in the traps, and these proved an excellent source of material for studying the spring development. Sections of plywood containing winter eggs were sawn from the trap and stapled on index cards ringed with a sticky barrier (31). These cards were placed in different sites (insectary, laboratory, and field) to determine the effects of exposure on rate and period of spring hatch. They were also used to study the hatching characteristics of brown mite eggs. Pieces of bark containing winter eggs were sliced from twigs and fruit spurs, attached to the cards, and exposed in various situations.

Three types of migration by the two species were studied: between twigs and leaves, up and down the tree trunk, and from herbaceous plants to hibernacula. Information on leaf-twig migration was obtained by the sampling procedure described above. Movement up and down the trunk was studied by banding the trunk and scaffold limbs with an adhesive. Similar methods were used in conjunction with the sampling technique and plywood traps to study the third type of migration.

Results of laboratory work were used to verify field observations. Potted clover and bean plants were used for mass rearings of the clover mite. Individual adults of both species were reared on apple or bean foliage placed on pads of absorbent cotton in petri dishes containing water (31).

Insect identifications were made by officers of the Entomology Division, Ottawa.

Bryobia arborea Morgan & Anderson

The brown mite is found throughout British Columbia in both commercial and abandoned orchards. Usually it is the only tetranychid mite present in the latter, apparently as in New York (19). The life-history of the mite on fruit trees in British Columbia is similar to that reported by workers from other areas who have studied it in orchards under the name *B. praetiosa*.

Spring Generation

Winter eggs begin to hatch in the late delayed-dormant to early "mouse ear" stage of leaf development of McIntosh and Delicious apples. In the Okanagan Valley this stage is reached sometime during April (Table 1). The eggs hatch

TABLE I
Spring development of *B. arborea* at Oliver, B.C., 1952 to 1955

Observation	1952	1953	1954	1955
First winter eggs hatched	–	–	April 15	April 28
First adults matured	–	–	May 10	May 11–18
First summer eggs laid	–	May 13	May 10–18	May 18–25
Peak in numbers of adults	May 14–21	May 20–27	May 18–31	May 25–June 1
First summer eggs hatched	May 14–21	May 27–June 3	May 31–June 8	June 8
Last adults of spring generation	June 4–11	June 10–17	June 8–16	June 15–22
Peak hatch of first summer eggs	May 28–June 4	June 10–17	June 16–22	June 15–22

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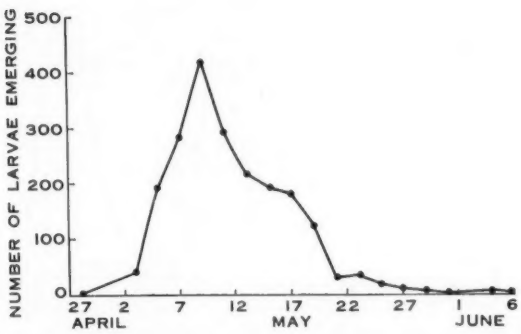

Fig. 1. Rate and period of hatching of winter eggs of *B. arborea* in an insectary, Summerland, 1955.

two to three weeks earlier than those of the European red mite, *Metatetranychus ulmi* (Koch), which start to hatch in the early pink stage. The period of hatch is relatively long (Fig. 1). The following phenological notes were made: May 6, five to ten per cent of peach blossoms open; May 9, all apricot blossoms open; May 11, first flower open on Duchess apple; May 12, first flower open on Anjou pear; May 13, McIntosh apple in pink stage.

Spring development on apple in Switzerland and Belgium appears to be slightly ahead of that in the Okanagan; hatching commences about the beginning of April and peak is reached about two weeks later (3, 5). In California a few winter eggs on almond trees hatch about the end of February, but the peak of hatch is not reached until about a month later, when almonds are in full bloom or in the petal-fall stage (43). Apparently, the hatch of winter eggs is associated with the development of orchard trees though the actual time of hatch may vary considerably in different countries and in different years.

After eclosion, the larvae move from the twigs to the "mouse ear" leaves and flower buds to feed. During the initial feeding period the colour changes from scarlet-red to greenish-brown. Under cool conditions in spring, the larval stage may last for over a week. When feeding is completed, practically all the larvae return to the rough bark of the twigs and fruit spurs to enter the first quiescent stage.

During the spring generation the nymphal and second and third quiescent stages average four to five days each. The adult stage is thus reached in about one month. A few adults mature within three weeks after the winter eggs begin to hatch. In 1954, the peak population of first-generation adults occurred about the third week of May; in 1955, at the beginning of June. Fig. 2 shows the development of all active stages of the generation in 1954 and 1955 in relation to mean air temperatures. After the third quiescent stage and a comparatively short feeding period of one to two days, the adults deposit summer eggs. On the other hand, Wybou (55) found that in Belgium the eggs were laid on the twigs within four days after the first adults were observed, but about two weeks elapsed before eggs were deposited on the leaves. In British Columbia, eggs are found on both leaves and twigs shortly after the first adults appear; initially a larger number are deposited on the twigs, but as egg-laying progresses the percentage laid on the leaves increases.

The eggs are deposited singly, from one to three per day. As the females live for two to three weeks, each probably lays about 30 eggs. The incubation

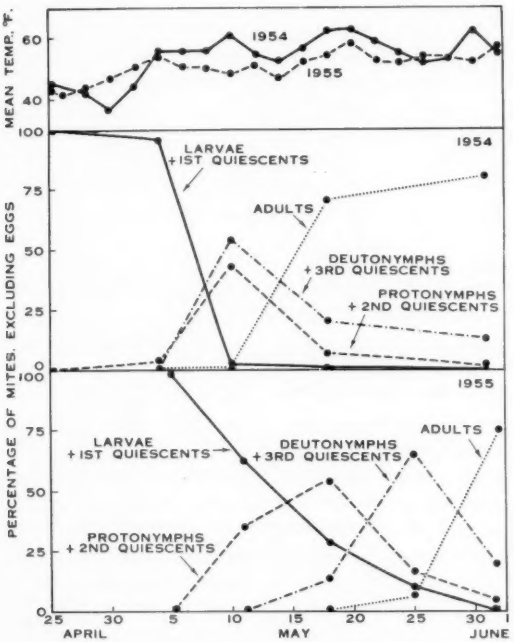

Fig. 2. Development of the spring generation of *B. arborea* and two-day averages of mean daily air temperature, Summerland, 1954 and 1955.

period at this time of year is two to three weeks; thus the second generation begins in the latter half of May or the first part of June.

During the spring generation practically all the larvae move back to the twigs to moult and most of the nymphs spend the second and third quiescent stages on the twigs. Most of the mites of the first summer generation moult on the leaves. The percentage of quiescent stages of the spring and first summer generations on the leaves and twigs in 1954 and 1955 were:—

	1954		1955	
	Leaves	Twigs	Leaves	Twigs
Spring generation	6.9	93.1	5.7	94.3
First summer generation	89.8	10.2	96.3	3.7

Some first-generation adults also move back to the twigs to oviposit.

Summer and Fall Generations

After completion of the spring generation in May or June, three similar cycles occur during the summer and fall. Thus in British Columbia the brown mite has a maximum of four generations per year (Fig. 3). In Ohio (28) and in the Palatinate, Germany (39), the mite also has four generations on apple. Seven generations have been reported from Switzerland (23), five from New York (19), three from Belgium (55), and two to three from Tasmania (10). Only three generations occur on almond in California (34, 43).

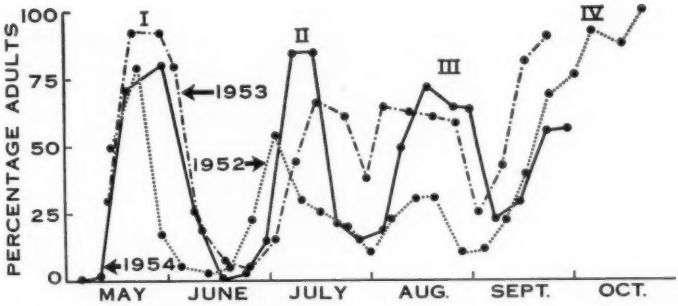

Fig. 3. Number of annual generations of *B. arborea* as indicated by the peaks in percentages of active stages that were adults, Oliver, 1952-1954.

Though the duration of the spring generation is well-defined, the summer and fall generations overlap. The incubation period during the summer is about 10 to 15 days, so that the first eggs hatch before the females have completed oviposition. The fourth generation of active and quiescent mites is comparatively small because the majority of eggs laid during August and September do not hatch until the next spring. Activity continues at a decreasing tempo until the first fall frosts.

The summer and fall generations live mainly on the leaves; there is comparatively little movement to the twigs for moulting or for summer egg deposition. In New York, the mites spend as much time on the twigs as on the leaves (19). In California, they live on the twigs and make excursions to feed on leaves only during favourable periods of the day (44). On pear and apple in Germany, Roesler (39) found that the mites stay on the bark most of the time and only move to the leaves to feed. In British Columbia, after completion of the spring generation in 1954, only 14 per cent of the eggs deposited on the twigs were summer eggs (Table II). Foliage and twig samples collected in early afternoon, at 11.30 p.m., and at 4.00 a.m. showed no evidence of diurnal movement. The only movement of importance occurs in the adult stage when the mites crawl to the twigs to lay winter eggs. This is not a mass migration for the deposition of winter eggs continues throughout the summer and fall. Banding of tree trunks and scaffold limbs showed that the adults do not move down to the trunk or ground.

Winter Stage

The winter is passed entirely in the egg stage. The bright red, spherical eggs are normally deposited on the lower sides of small twigs and fruit spurs. When the mites are numerous, the eggs are often found on the sides of the twigs and spurs, on small limbs, and on the calyx-ends of apples. The lower surfaces of limbs appear brownish-red when they are covered with masses of winter eggs. More eggs are deposited near the top of the tree than on the lower limbs, particularly in heavy infestations. This mite does not deposit winter eggs on the tree trunk.

It was thought until recently that the brown mite started to lay winter eggs about the same time as the European red mite, that is, in the first part of August. Collections in 1952 and 1953 showed that a progressive build-up of eggs started early in the summer. As few egg chorions or newly hatched larvae were found

TABLE II
Percentages of viable summer and winter eggs of *B. arborea* on apple twigs on various dates in 1954 at Oliver, B.C.

Collection date	Number of eggs in sample	Summer eggs	Winter eggs
June 29	31	61	26
July 7	160	1	85
July 14	145	17	71
July 20	182	10	90
July 26	185	6	90
Aug. 4	117	4	85
Aug. 11	318	0	92
Aug. 17	210	0	87
Aug. 25	223	17	72
Aug. 31	216	1	94
Sept. 7	188	1	87
Sept. 14	392	0	97

on the twigs, evidently the majority of these eggs did not hatch during the summer. In 1954 and 1955 twig samples were collected at weekly intervals from June to September and the eggs allowed to hatch in the insectary. A few eggs that had been deposited early in June did not hatch until the following spring. By the first week of July, 85 per cent of the eggs on the twigs and fruit spurs were winter eggs (Table II). Some of the first winter eggs were probably deposited by adults of the spring generation. If this is the case, part of the population must complete only one generation annually; weekly sampling showed that this brood is only a small part of the population. Summers (43) has also reported that on almond in California the mite begins to deposit winter eggs early in the summer and that 65 to 70 per cent of these are viable. Approximately 90 per cent of the winter eggs incubated at Summerland in a constant temperature cabinet at 65°F. and 80 per cent relative humidity were viable. In the insectary, percentage viability ranged from 85 to 100.

Host Plant Preference

As far as is known, *B. arborea* feeds only on orchard trees. In the Okanagan Valley, apple is the preferred host but plum and prune sometimes suffer economic injury. The apple varieties are attacked in decreasing order as follows: Delicious, Newtown, McIntosh, Jonathan, and Winesap. *B. arborea* also occurs on cherries, pears, and peaches but it is not an economic pest on these. Only rarely are apricots attacked in this area. Treherne (48) suggested that apricots and quince were naturally resistant to this mite in Western Canada. In contrast, in the San Joaquin and Sacramento valleys of California, the mite is an economic pest of apricots, peaches, and almonds (43). Thompson (12) considered that this mite originated on almond trees and spread to other fruit trees. In Germany, Roesler (39) found the heaviest infestations on pear, but apple and peach also suffered damage.

It has been reported that the mite also attacks native deciduous trees such as elm and poplar, and coniferous trees such as cedar and spruce (25, 37, 40). In British Columbia, *B. arborea* has not been found outside of orchards, but *B. praetiosa* has been observed on the trunks of native trees. These trees were not true hosts; the rough surfaces of the trunks merely served as hibernacula.

Injury

Foliage injury caused by the brown mite on apple is very noticeable in the "mouse ear" stage of leaf development. At that time extensive damage may be caused by large numbers of larvae feeding on the primary leaves. Damage to the leaves and flower buds may hinder the opening of the flowers. In Australia, the young mites attack the blossoms and cause considerable damage to leaf buds (2, 13). In the summer the foliage damage resembles that caused by the European red mite except that the injury at first appears as discrete off-colour areas rather than as a uniform discolouration of the leaf. As injury progresses, the foliage becomes pale green, then yellow, and finally bronze. Badly damaged leaves are thin and leathery to the touch. Premature leaf drop has not been observed in British Columbia, although as many as 600 eggs and active mites per leaf were counted. In Tasmania, Evans (10) has reported leaf fall from severe infestations. There, the most evident damage is seen in late summer, especially in seasons of low rainfall. Thomas (46) previously reported from the same state that the most serious damage was that which occurred in early summer and affected the next year's fruit buds. In California, entire areas of almonds have been defoliated by the mite (21). It has also been reported that the injury reduces the size, adversely affects ripening (46), and malforms apples (28).

Natural Control

The following species of mites and insects have been reported in the literature to attack the brown mite: the mites *Mediolata novae-scotiae* Nesbitt and *Typhlodromus tiliae* Oudms. (20); the coccinellids *Psyllobora taedata* Lec. (53) and *Stethorus punctillum* Ws. (36); the neuropteron *Conwentzia psociformis* (Curt.) (54); and the thrips *Scolothrips sexmaculatus* (Perg.) (5), *Leptothrips mali* (Fitch) (6), and *Haplothrips faurei* Hood (20).

In British Columbia, the following species were observed feeding on the mite: the mites *Mediolata* sp., *Typhlodromus tiliae* Oudms., and *T. rhenanus* Oudms.; the coccinellids *Adalia bipunctata* (L.), *A. frigida* (Schn.), *Chilocorus stigma* Say, *Coccinella transversoguttata nugatoria* Muls., *C. transversoguttata quinquenotata* Kby., *Cycloneda sanguinea* (L.), *Psyllobora* sp., and *Stethorus picipes* Csy.; the anthocorids *Anthocoris* spp.; and the mirid *Campylomma verbasci* (Meyer).

The role of these predators as biological control agents was not fully determined. However, it was observed that *T. tiliae* readily feeds on eggs and active stages of the brown mite on the coastal areas of the province. This predator is rarely found in the Okanagan Valley. In Nova Scotia, *T. tiliae* feeds on the brown mite only under pressure of starvation (20). One predacious mite always found in association with the brown mite in British Columbia is *Mediolata* sp. Two insect predators of probable economic importance here are *Chilocorus stigma* and *Campylomma verbasci*, the adults of which have been found feeding voraciously on clover mite larvae in early spring. *S. picipes*, a common mite predator in sprayed orchards, feeds principally on the European red mite and *Tetranychus* spp.; it rarely attacks the brown mite. A closely related species, *S. punctillum*, has similar habits in Ontario (36). In the Okanagan Valley, predators appear to play only a minor role in the control of *B. arborea*.

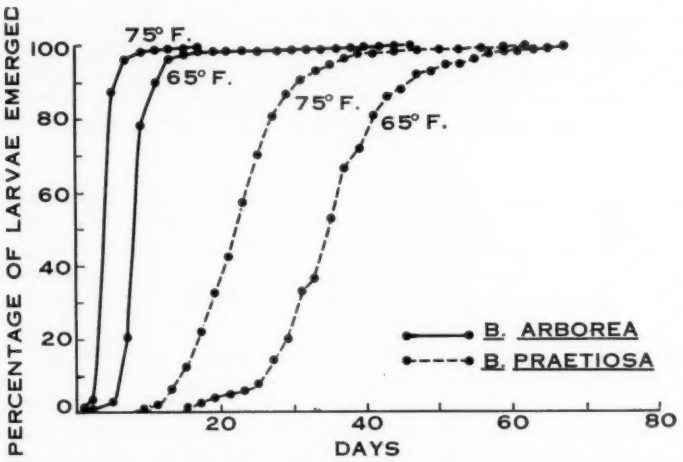

Fig. 4. Rate and period of hatching of winter eggs of *B. arborea* (2,250 specimens) and *B. praetiosa* (39,600 specimens) when incubated at 65° and at 75°F.; relative humidity, 75 to 85 per cent.

Bryobia praetiosa Koch

The clover mite is found throughout British Columbia. Though it occurs on herbaceous plants in fruit growing regions, it is not a pest of orchard trees. The mite attracts attention primarily in and near homes. It is the diverse habits of the mite on herbaceous plants that have caused the difficulty in resolving the life-histories of the *B. praetiosa* complex.

Spring Generation

The clover mite overwinters in both the egg and active stages, and consequently spring development follows two courses. The winter eggs hatch and give rise to a spring generation. The overwintered adults deposit spring eggs, the progeny of which also form a portion of the spring generation. The overwintering larvae and nymphs usually constitute an insignificant part of the population. In the spring they mature and their progeny form a slightly delayed portion of the spring generation.

Hatching of Winter Eggs.—Larvae of the clover mite hatch from winter eggs very early in the spring, long before other species of phytophagous mites become active. In 1955, at Vancouver, eclosion from winter eggs started about February 15 during a period of relatively warm weather; the maximum temperature for the month was 50°F. Larval activity continued until February 27, when freezing temperatures set in. The larvae, which had been feeding on grass and moss, moved to protected places in fence posts and beneath bark scales, where they became dormant. During these two weeks very few mites had developed beyond the larval stage. After an unusually cold period of 17 degrees of frost on March 3, approximately 30 per cent of the larvae died, but only those that had not fed were killed.

At Summerland, hatching of winter eggs commenced on March 12 in 1955, only two days after the last snow disappeared. Maximum temperatures for the week before hatching ranged from 28° to 46°F. and minimum temperatures from 10° to 34°F.

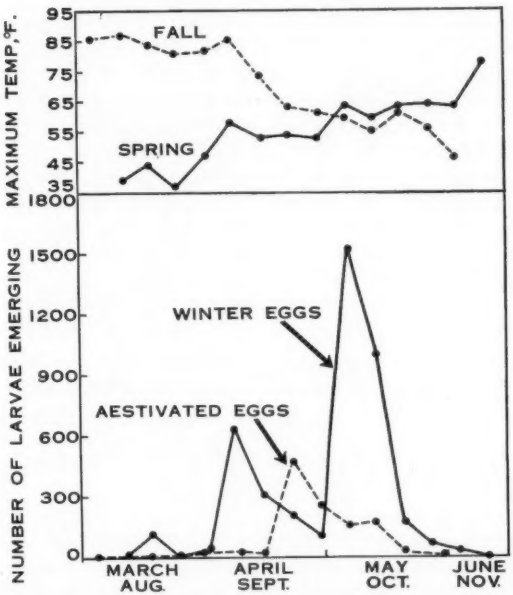

Fig. 5. Rate and period of hatching of winter and aestivated eggs of *B. praetiosa* in the field and weekly averages of daily maximum air temperature, Summerland, 1955.

Under suitable weather conditions, embryonic development in the winter eggs appears to be a continuous process. By late fall a large portion of the eggs contain fully developed embryos. In ideal locations (i.e., on southern sides of buildings) where additional heat is received in late fall, the eggs may hatch and the mites overwinter in immature stages.

The rate and period of hatch of winter eggs of the mite were studied in constant temperature cabinets. Samples of eggs collected in the latter part of December from various levels on a tree trunk were incubated at 65° and 75°F., and 75 to 85 per cent relative humidity. At each temperature hatching commenced within 12 to 18 hours and the peak of hatch was reached in four and eight days at 75° and 65°F., respectively. At 75°F. brown mite eggs did not begin to hatch until nine days after they were placed in the cabinets. This indicates that all embryonic development of brown mite eggs takes place in the spring. The rate and duration of hatching for *B. praetiosa* are compared with those of *B. arborea* in Fig. 4.

Data obtained from plywood traps placed on the lawn site in September, 1954, showed that rate of spring hatching is closely associated with maximum air temperatures (Fig. 5). The hatching period is very long, extending from March 11 to June 10 in 1955. Thus, towards the end of this period, all active stages are present simultaneously.

Rate of hatching depends to a great extent on the exposure of the oviposition site. Eggs deposited on the south sides of tree trunks, for example, are subjected to the heat of the sun early in the spring, and hatch before those laid in other exposures. The rates of hatching were studied by placing sections of plywood containing eggs on cards ringed with a sticky barrier and attaching the cards to the north and south sides of traps placed on the open lawn. The rate of

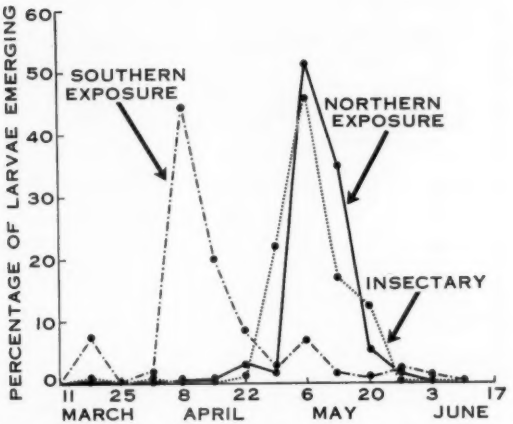

Fig. 6. Rate and period of hatching of winter eggs of *B. praetiosa* in an insectary and on south and north exposures in the field, Summerland, 1955.

hatching in a nearby insectary was followed simultaneously. As illustrated in Fig. 6, the peak of hatching in southern exposures occurs well ahead of those on the north. Hatching is retarded in an insectary and is comparable only to that of a northern exposure.

Deposition of Eggs by Winter Adults.—The winter adults have an extremely low threshold of activity. They become noticeably active about the same time as winter eggs begin to hatch, and may lay eggs during any comparatively warm period of the winter. With the advent of spring weather the rate of oviposition accelerates. The winter adults deposit eggs immediately they become active, either before or shortly after an initial feeding period. On the other hand, the small number of immature mites that overwinter may require a few days to several weeks to mature before ovipositing. Overwintered adults continue to oviposit until about the middle of April. In 1955, the hatching period of these eggs extended from May 4 to the middle of June (Fig. 8).

Active Stages of the Spring Generation.—Upon eclosion, the bright red, disc-shaped larvae are positively geotropic and either migrate or drop from the egg site to herbaceous plants, where they begin to feed. During the initial feeding period they become dark green and almost spherical. On completion of the larval stage, the mites move back to sheltered locations to moult. Like the larvae, the newly emerged protonymphs, deutonymphs, and adults are dorsoventrally flattened, but after feeding the body becomes distended and the normal shape is attained. Practically all the mites migrate to a sheltered location to moult and oviposit; very few quiescent individuals are found on herbaceous plants. For example, in a sample collected from grass on May 19, 1955, the following numbers were present: eggs, 0; larvae, 30; first quiescents, 0; protonymphs, 32; second quiescents, 4; deutonymphs, 34; third quiescents, 2; and adults, 148.

The mites are unusual in their immediate response to disturbance and their habit of coating eggs with foreign material. The mites drop from plants at the slightest disturbance, curl up their legs, and "play possum". Venables (49) has described how the adult covers its egg with bits of dust or other material. In its search for suitable particles, the adult may move a few centimetres away from the newly laid egg.

Development of the active stages of the spring generation is rather slow in the cool days of March and April. On April 18, 1955, approximately five weeks after winter eggs began to hatch, a sample of mites taken from the lawn site showed the following percentages in each stage: larvae and first quiescents, 28.6; protonymphs and second quiescents, 50.9; deutonymphs and third quiescents, 14.9 and adults, 5.6. Doubtless the adults were the remnants of those that had overwintered whereas most of the immature stages had probably developed from winter eggs. Thus in five weeks only 15 per cent of the population had developed beyond the second nymphal stage. Against buildings, where the winter eggs had hatched in the fall and the mites had overwintered chiefly as larvae, 35 per cent had passed the second nymphal stage by the same date. Here, too, the rate of development appeared to be very slow, but because the mites had overwintered as larvae they developed further.

The first adults of the spring generation begin to mature shortly after the last overwintered adults have died, that is, during the latter half of April. Hence, oviposition is almost continuous throughout the spring. During the first week of May, 1954, the mites in the three sites (lawn, commercial orchard, and neglected orchard) were in similar stages. About 80 per cent were adults, 10 per cent immature stages, and 10 per cent eggs. The peak adult population is reached during May. These adults move to dry protected sites to oviposit and in so doing frequently attract the attention of householders. Beginning about the end of April and reaching a peak during May, they lay large numbers of eggs. The majority of eggs deposited in the warm weather of summer do not hatch but aestivate until the cooler days of early fall.

In June, the adults begin to decline in numbers because most have deposited their eggs and died. On June 22, 1955, for example, only 40 specimens were obtained by beating the grass on the lawn site, whereas 300 to 400 were collected in May in a similar sample. Since the winter eggs and eggs from overwintered adults have all hatched by the first part of June, the immature stages practically all mature by the end of the month. In 1955, all the mites in a sample taken on June 30 were adults. Spring-generation adults may be found on herbaceous plants until the middle of July.

Summer Generations

A few of the eggs deposited by the spring adults do not aestivate but hatch in early summer and give rise to continuous summer generations. A similar phenomenon occurs in Switzerland. Mathys' (23) biotype IV, which infests herbaceous plants, is primarily univoltine though a small part of the population produces summer generations. He found that each summer generation was smaller than the preceding one and that the adults of each generation laid a proportionately larger number of eggs that overwintered. These details were not verified in the Okanagan Valley because the populations during the summer were too small. Attempts to induce deposition of aestivating eggs by rearing mites at relatively high temperatures were unsuccessful.

Five summer generations were reared in the laboratory between May and September, 1955. This is probably more than would occur in the field.

Fall Generation

Aestivated eggs deposited in May and June began hatching in late summer or early fall. In 1954 and 1955, the peak emergence of fall larvae followed the first period of cool, fall weather. In both years, the rate of hatching increased markedly shortly after the maximum daily temperature dropped below 70°F.

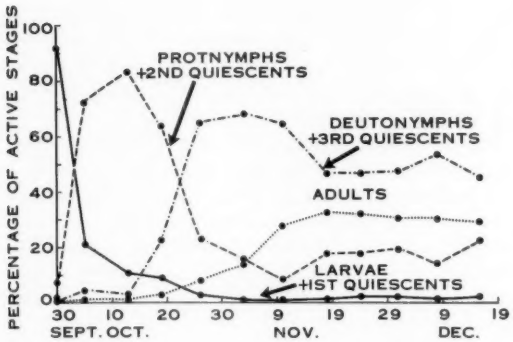

Fig. 7. Development of the fall generation of *B. praetiosa* on laboratory lawn as indicated by weekly counts of mites in a plywood trap, Summerland, 1955.

In 1954, the increased rate of hatching occurred about September 1; maximum temperatures first fell below 70°F. for a period beginning on August 22. In 1955, such a period of cool weather did not occur until September 13 and the increase in larval emergence did not commence until September 22 (Fig. 5). As indicated by collections of larvae, hatching in the field continued for over a month. Although fall frosts first occurred on October 6, many larvae hatched after that date. Aestivated eggs placed on larval emergence cards in the field hatched between September 22 and November 3, 1955 (Fig. 8).

The active stages of the fall generation continue development throughout the fall. In 1954, practically all mites had matured before winter weather occurred. The first winter eggs were deposited about the end of September. Large masses of eggs were laid throughout October and in early November. Owing to the late hatch of aestivated eggs and the cool weather, development was greatly retarded in 1955. Although a few winter eggs were laid as early as September 30, the majority of the mites had not developed past the first quiescent stage by that date. One month later most of the mites had only developed to the third quiescent stage (Fig. 7). Winter weather commenced on November 11, with minimum and maximum temperatures of 14.9° and 17°F. As a result, the fall oviposition period for most of the adults was extremely short and very few winter eggs were laid. Some eggs were laid throughout November, even during periods when the maximum air temperature did not rise above 32°F.

By removing third quiescent nymphs from the traps and confining them without food, it was determined that they can give rise to adults capable of laying some eggs without feeding. This must also occur in the field in late fall when the ground is covered with snow and females depositing eggs are unable to feed on herbaceous plants.

Winter Stages

Fall weather conditions influence the manner in which the clover mite overwinters. In the comparatively long, warm fall of 1954, most mites completed one generation. They wintered principally as eggs and adults, approximately in the ratio 50:1. The fall of 1955 was relatively short and cool, so that fewer mites completed development (Fig. 7) and they overwintered mainly as eggs, deutonymphs, third quiescents, and adults. In contrast with 1954, the ratio of eggs to other stages was only 2:1.

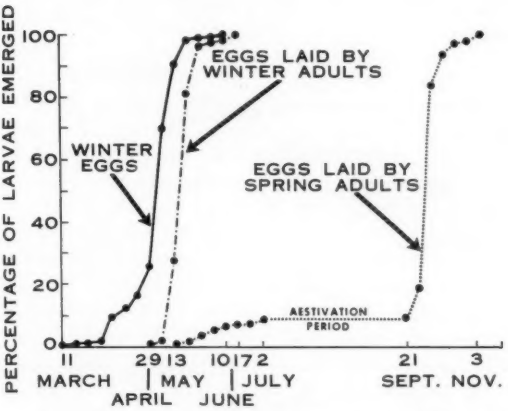

Fig. 8. Number of annual generations of *B. praetiosa* on laboratory lawn as indicated by the rate and period of hatching of eggs deposited in plywood traps, Summerland, 1955.

Number of Generations

The clover mite is predominantly bivoltine in British Columbia (Fig. 8). The summer is passed as aestivating eggs and the winter as overwintering eggs and active stages (Fig. 9). A small part of the population completes a succession of summer generations instead of aestivating as eggs. No evidence of a univoltine type was found in this investigation. Venables (49) stated that the mite infesting grasses and low-growing herbaceous plants has but one generation annually. He did not refer to a fall generation or to overwintering active stages. He thought that eggs deposited in the spring did not hatch until the following year. Of the four biotypes studied by Mathys (24), biotype IV is the only one with habits similar to those of the clover mite in British Columbia. Nevertheless, the life-histories of the clover mite and biotype IV differ in that biotype IV is predominantly univoltine. Like the clover mite, a small part of biotype IV completes a succession of summer generations. Mathys made no mention of aestivating eggs or a fall generation. Although a bivoltine type of the clover mite has not been previously reported, it may be concluded from the literature that it is fairly prevalent in North America, for migrations of adults into houses are common in many parts of the continent during both spring and fall (22, 27, 35, 51).

Host Plants and Injury

In addition to the host plants reported by other workers, the clover mite was found feeding on the following garden plants in British Columbia: rock-cress, *Arabis* sp.; aubrietia, *Aubrietia deltoidea* DC.; bleeding-heart, *Dicentra spectabilis* Lem.; daffodil, *Narcissus pseudonarcissus* L.; garden rocket, *Hesperis matronalis* L.; poppy, *Papaver* sp.; primrose, *Primula* sp.; rockery phlox, *Phlox* sp.; salvia, *Salvia* sp.; sweet alyssum, *Alyssum* sp.; and western trillium, *Trillium* sp. Chrysanthemum, *Chrysanthemum* sp.; geranium, *Geranium sanguineum* L.; and wallflower, *Cheiranthus cheiri* L., do not appear to be attacked.

Injury produced by individual mites resembles a winding, etiolated trail; Riley and Marlatt (37) described this as imitating to perfection the mines of certain Tineidae. When present in large numbers the mites cause extensive damage to clovers, lawn grasses, and ornamental flowers. The foliage may turn

yellow or brown and then wilt. Both foliage and floral injury were observed on flowering plants.

Household Pest

In British Columbia, complaints of infestations of the clover mite in homes are often received in the spring, but never in the fall. Fall migrations occur near homes but go unnoticed, possibly because the mites do not enter houses but move only to the sheathing to oviposit and hibernate. Also, as householders are not gardening at that time of year, mites on the outer walls may readily escape notice. The invasion of homes in May is by adults of the spring generation rather than by overwintered adults coming out of hibernation. Householders become concerned because of their natural aversion to crawling creatures. The clover mite is particularly obnoxious in this respect because it swarms in large numbers over floors, furniture, and windows. The mite does not attack man, but there have been cases of mental derangement associated with the invasion of homes. In one extreme case at Summerland, medical attention was required.

Natural Control

No predators of the clover mite on herbaceous plants have been reported previously. In the Okanagan Valley, two mites and one insect predator were observed feeding on the mite. The mite species are *Typhlodromus cucumeris* Oudms. and an unidentified bdellid mite. The only insect predator definitely known is *Anthocoris melanocerus* Reut., but other anthocorids such as *A. antevolens* White probably attack the mite.

The most important predator appears to be the bdellid mite: a large red mite, very active from early spring to late fall, that was observed feeding on most stages of the clover mite. Its bright orange, elliptical eggs are deposited in the same sites as clover mite eggs. This predator was collected on cover crops and on the trunks of orchard trees, but never on the foliage of fruit trees.

T. cucumeris is also a voracious feeder on clover mite eggs and immature stages. In a laboratory rearing a single adult consumed six larvae in one night. In the field the life cycles of the predator and host are so different that the predation value of *T. cucumeris* is probably very limited. When the predator is most active, *B. praetiosa* is in the aestivating egg stage. Probably *T. cucumeris* remains on herbaceous foliage feeding on other phytophagous mites and does not seek out the aestivating eggs.

Anthocorids are commonly associated with the clover mite only from late fall to early spring, as they hibernate in similar sites. During the summer these predators feed largely on aphids in aerial portions of trees.

Effects of Weather on *B. arborea* and *B. praetiosa*

The influence of weather on the abundance and habits of *Bryobia* spp. has been mentioned frequently in the literature. Increased populations have been ascribed to hot, dry weather by some authors (9, 10, 48), but others maintain that cool weather favours development (8, 12, 43).

In the semi-arid Okanagan Valley the brown mite first became an orchard pest, and the clover mite a nuisance in homes, in 1950. This coincided with the beginning of a cool, wet period. Annual precipitation up to 1948 was 10.7 inches (33, pp. 6-10). For the years 1949 to 1954, the average increased to 12.1 inches. Temperatures during this period were also below normal. After a prolonged cool spring, the summer of 1955 saw the return of hot weather more typical of this area. Thereupon, the brown mite population noticeably declined

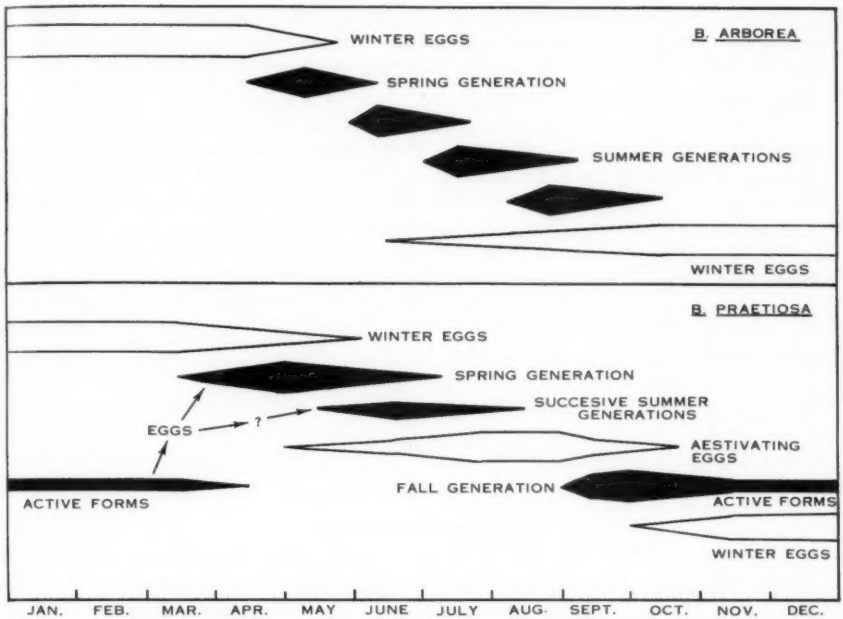

Fig. 9. Life-histories of *B. arborea* and *B. praetiosa*, based principally on data obtained in 1954, Summerland and Oliver.

in the neglected orchard at Oliver and the summer generations of the clover mite on the lawn site were smaller than in 1954. Large numbers of aestivating clover mite eggs failed to hatch though embryonic development appeared to have been completed; presumably the hot, dry summer weather was responsible.

The temperature requirements of the two species differ. The clover mite has a much lower threshold of development than the brown mite. This characteristic is reflected in seasonal development (Fig. 9). Winter eggs of the clover mite begin to hatch almost as soon as the snow leaves the ground, when maximum temperatures are between 40 and 50°F.; brown mite eggs do not hatch until a month later, when the maximum temperature is at least ten degrees higher. With the onset of summer weather, the active stages of the clover mite decline in numbers, whereas the rate of development of the brown mite increases. In the fall the trend is reversed; brown mite activity ceases while the clover mite develops another generation. Brown mite eggs pass the winter in diapause; winter eggs of the clover mite continue development as long as suitable temperatures prevail, and become dormant only during periods of cold weather. The diapause of brown mite eggs cannot be broken until they are subjected to a long exposure of winter weather (43).

Summary

The brown mite, *Bryobia arborea* Morgan & Anderson, lives only in the aerial portions of orchard trees. It passes the winter in diapause in the egg stage on twigs and branches. The eggs begin to hatch in the late delayed-dormant to early pink stage of apple bud development, and continue hatching until apples are in full bloom. The mite has a maximum of four generations annually. As

deposition of winter eggs commences in June, small portions of the population have only one to three generations annually. Deposition of winter eggs continues until October, when the adults die. This species does not migrate except from leaves to twigs and small limbs.

The clover mite, *B. praetiosa* Koch, has more diverse habits. It lives on a wide range of herbaceous plants, from which it often moves into dwellings; seldom is it found in the aerial portions of trees. This mite is considerably more tolerant of cold than the brown mite and may become active at temperatures slightly above freezing. Although it overwinters chiefly in the egg stage under bark scales of tree trunks, in cracks in fence posts, under sheathing of buildings, or in other dry, protected sites, it may overwinter in any of the other stages. The number of active mites overwintering and the percentage in each stage depend upon fall weather conditions. The winter eggs begin to hatch very early in the spring, usually a month or more before those of the brown mite. One generation is completed during the spring and early summer months. Most of the eggs deposited by this generation aestivate until September, but a small number hatch in early summer and give rise to a succession of summer generations. Aestivated eggs begin to hatch about September. Only one generation is completed during the fall.

Acknowledgments

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Notes on Larentiinae—New Records and Corrections (Lepidoptera: Geometridae)

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Recent studies in the Larentiinae revealed two new occurrences for North America, one apparently indigenous and the other introduced. A third species discussed below has stood in the American lists for over fifty years on the basis of a misdetermination, and should be removed.

Lygris populata L.

The early literature contains many references to this species in North America but it is almost certain that all such records can be attributed to the superficially similar Nearctic species, *Lygris propulsata* Wlk. During current investigations in the genus *Dysstroma*, I encountered Alaskan specimens that proved to be genuine *Lygris populata*. These specimens, in the collections of three different museums where they were misdetermined as, or mixed in with, material of *Dysstroma glacialis* Hlst., are as follows:

Unga, Alaska, no date, 4 ♂ ♂, 1 ♀. Barnes collection (U.S. National Museum).

Mt. McKinley National Park, no date, F. W. Morand, 1 ♀. Barnes collection (U.S.N.M.).

Nulato, Alaska, above timberline, 7-26-16, 1 ♂. S. E. Cassino collection (Museum of Comparative Zoology, Harvard College).

Goodnews River, Alaska, Aug., 1 ♀. S. E. Cassino collection (M.C.Z.).

Mt. Dewey, Alaska, Aug. 19, 1923, 1 ♀. (Los Angeles County Museum).

I compared this material, including both male and female genitalia, with a European series kindly provided by Dr. Walter Forster of Munich, and the similarity of color and maculation at once suggests that they are conspecific. The Alaskan examples are noticeably smaller, but this may be expected of specimens from a boreal environment. The genitalia of the two populations are nearly identical, except that the Alaskan female shows a more slender and lengthened aspect in the ductus bursae and papillae anales. There is no difficulty in separating *populata* from *propulsata*; the latter has strikingly different genitalia that belie a truly close relationship.

Lygris populata is clearly representative of that section of the Alaskan fauna with strong Palaearctic affinities–species whose limited penetration of the New World would seem to imply a relatively recent crossing of the Bering Strait.

Perizoma alchemillata L.

On a collecting trip to the vicinity of St. John's, Newfoundland in 1954, I was surprised to take this European moth at light in two localities:

Donovan's, 7 miles W. of St. John's on the Topsail Road, July 28, 31, 1954, 2 ♀ ♀.
Mt. Pearl, near St. John's, July 24, 1954, 1 ♂, 4 ♀ ♀.

As the collecting sites were about 2½ miles apart, it appears that the species is at least locally established, and we can assume that it was accidentally introduced.

Thera variata Schiff.

In his paper on the Lepidoptera of the Harriman Expedition (Proc. Wash. Ac. Sci., v, 2, p. 495, 1900), Dyar erroneously accredited this species to our fauna, basing his determination on twelve specimens from Popof Island, Alaska, July 12-15, 1899, T. Kincaid, collector. My *Dysstroma* studies led to an examination of eleven of the original twelve, eight in the U.S. National Museum, two in the American Museum of Natural History and one in the Museum of Comparative Zoology, Harvard College. By both maculation and genitalia, these unquestionably represent a *Dysstroma*, probably a dwarfed Aleutian race of *D. walkerata* Pears. Thus in calling them a small variety of *Mesoleuca truncata* Hufn., the initial determination which Dyar "corrected", Hulst was not far from the truth.

I am indebted to Dr. Frederick H. Rindge of the American Museum of Natural History for bringing to my attention the probability that the Nearctic record for *Thera variata* was based solely on this one series from the Harriman Expedition. I am also indebted to the authorities of the museums mentioned for the loan of material and the privilege of making genitalic preparations.

Genus *Hydria* Hubner

When preparing my recent paper, The North American Species of *Calocalpe* Hübner (Can. Ent., v. 87, pp. 325-330, 1955), I was unable to find any genotype designation for *Hydria* Hbn., and consequently followed the last check list (McDunnough, 1938) in using the monobasic name *Calocalpe* Hbn. for the genus. As was soon pointed out to me by my teacher, Dr. J. G. Franclemont of Cornell University, a genotype designation actually does exist. Grote, in a paper of 1902, Die Gattungsnamen der europäischen Geometriden (Allgemeine Zeitschrift für Entomologie, v. 7, p. 471), states: "*Hydria* Hübn. 1806 Tent. Der Typus ist *undulata. Calocalpe* Hübn. Verz. 330 ist Synonym".

Thus *Hydria*, the older name, restricted through Grote's designation, should be used in place of *Calocalpe*.

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Observations on the Biology of Certain Tortricids in Young Coniferous Plantations in Southern Ontario[1]

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Since 1953, plantation owners in southern Ontario have suffered serious losses from a group of tip-infesting insects of the family Tortricidae. These insects live primarily on the herbaceous ground-cover plants but may ascend trees under about 3 feet in height and feed on the new shoots during May and June, killing or injuring the leaders and causing serious growth deformities. Five species are involved, of which *Tortrix alleniana* Fernald and *T. pallorana* Robinson are common, and *Archips rosaceana* Harris, *Sparganothis sulfureana* Clemens, and *S. unifasciana* Clemens occur only as scattered individuals among larger populations of the two common species. This paper records the most salient points in the life history and general ecology of *T. alleniana* and *T. pallorana*, with notes on the other three species.

Tortrix alleniana

Hosts and Distribution

T. alleniana has been classed as a general feeder (Forbes, 1923). McDunnough (1933) reared a number of larvae on wild bergamot, *Monarda fistulosa* L., and Venables (1924) found eggs on alfalfa, *Medicago sativa* L., and snowberry, *Symphoricarpos* sp., and larvae feeding on apple, *Malus pumila* L.

During this study, feeding larvae were taken from the following hosts:

Melilotus alba Desr.–white sweet clover
Medicago sativa L.–alfalfa
M. lupulina L.–black medick
Trifolium pratense L.–red clover
Fragaria virginiana L.–strawberry
Potentilla recta L.–cinquefoil
Silene cucubalus Wibel.–bladder campion
Stachys palustris L.–hedge nettle
Taraxacum officinale Weber–dandelion
Tragopogon pratensis L.–yellow goat's beard
Aster macrophyllus L.–large-leaved aster
Solidago spp.–goldenrods
Cornus stolonifera Michx.–dogwood
Prunus virginiana L.–chokecherry
Malus pumila L.–apple
Salix sp.–willow
Fraxinus americana L.–ash
Pinus sylvestris L.–Scots pine
P. strobus L.– white pine
P. banksiana Lamb.–jack pine
Picea glauca (Moench) Voss.–white spruce

It is emphasized, however, that this insect was found on coniferous hosts only during the months of May and June.

Forbes (1923) lists the distribution of this species as Maine to Manitoba, and Venables (1924) records its presence in the Okanagan Valley in British Columbia.

1Contribution No. 414, Forest Biology Division, Department of Agriculture, Ottawa, Canada.

Life History

The life history was determined from field observations supplemented by laboratory rearings. This insect has one generation per year and overwinters as a young larva.

Egg

Although the larvae feed on a wide variety of hosts, oviposition is restricted mainly to white sweet clover and alfalfa. After an intensive search of several heavily infested plantations, only two egg masses were found on other hosts, one on bladder campion and another on cinquefoil. The eggs are deposited early in June on the central part of the upper side of the leaves. They appear as elongate, irregularly shaped, shingled masses averaging 6 mm. long by 2 mm. wide. The number of eggs per mass varies from 19 to 141, with an average of 47. The fresh masses are light greenish-yellow, but as they mature they become bright orange. The eggs hatch in approximately 15 days.

Larva

All viable eggs in a mass hatch almost simultaneously and the young larvae move rapidly over the leaf. Dispersion takes place at this time, and if a strong breeze is blowing, the larvae from a single egg mass may be distributed quite widely within 15 to 20 minutes. In the absence of wind, the young larvae move to the edge of the leaf and drop on silken threads, or they may crawl off the leaf by way of the petiole. The dispersed larvae seek the new, still-unfolded leaves on the upper parts of the plants, tie the two halves of a single leaf together, and begin feeding on the upper epidermis. They feed in this manner until mid-August, and then spin silken hibernacula within the folded leaves and remain there until spring. The majority of the population hibernate in the third instar, but a few individuals appear to do so in the second or fourth instars.

The larvae begin feeding on the herbaceous plants early in May before the leaves of shrubs and trees have appeared. As they increase in size, their presence becomes more noticeable since they tie several leaves together with an abundance of silk. Early in June, at the time when the buds of Scots pine and white pine have elongated fully and shed their husks, but before the lateral members have spread away from the central member of a shoot cluster some of the larvae may wander away from the herbaceous plants in search of other hosts. These insects will, at this time, ascend any tree or shrub growing close to their former host, but they will rarely go higher than 3 feet. Here they continue to feed in the same manner as before, tying or folding several leaves or shoots together and feeding within the sheath. The larvae feeding on alfalfa or white sweet clover will rarely, if ever, leave these plants for different hosts, and only some of those feeding on the other herbaceous plants will migrate. Although no accurate estimate of the percentage of larvae that leave their early hosts can be given, it is believed that less than 50 per cent do so.

The newly hatched larvae of *T. alleniana* are about 2 mm. long, the head is large, and setae on the abdomen are prominent. The head capsule, prothoracic shield, and anal plate are tan-yellow with a dark smudgy appearance. The abdomen is tan-yellow with a slight greenish cast on the dorsum.

The mature larvae are about 23 mm. long, and little can be added to the following description by Venables (1924): "The head is pale yellowish, with dark brown markings: thoracic shield pale yellowish, with a dark brown triangular mark on the caudo-lateral margin on each side. The thoracic shield is divided by a narrow pale line, which is bounded on each side by a narrow pale brown stripe which is considerably wider posteriorly. The whole of the dorsum above the spiracles is very dark green in colour, with the tubercles conspicuous,

and of a dull yellowish-white. Below the spiracles the body is pale yellowish, with the tubercles of that region light in colour and prominent. In the centre of each tubercle there is a dark brown circular spot, from the centre of which arises a single pale seta. The anal plate is paler than the dorsum and bears eight setae. There is a pronounced anal fork beneath the posterior margin of the anal plate. The thoracic legs are pale brown; prolegs concolorous with the venter. Spiracles dark brown." In Ontario considerable variation in the dark brown markings on the head and prothoracic shield was noted, but their mere presence served to distinguish this species from other tortricids encountered.

Pupa

The pupa is 12 to 15 mm. long, dark brown above, and lighter reddish-brown below. Pupation takes place within the feeding sheath in mid-June, and lasts for about two weeks.

Adult

The adults appear about the first of July and the flight lasts approximately 10 days for the main part of the population. However, a few mature larvae of the overwintering generation can still be found when most adults are laying their eggs, so that scattered adults may appear throughout July and early August. The adults emerge during the daylight hours, rest quietly on the vegetation during the day, and breed and oviposit at night. The moths show a pronounced colour difference between sexes, the males being several shades lighter than the females.

Parasitism

Parasitism was not an important mortality factor in the populations sampled during this study. Mortality of larvae varied from 2 to 12 per cent and the following parasites were recovered:

Campoplex atridens Tow., *Phytodietus vulgaris* Cress., *Phryxe pecosensis* (Tns.), and *Gravenhorstia* sp.

Pupal mortality varied from 0 to 4 per cent and the following species were recovered:

Horogenes rosanae (Vier.), *Itoplectis conquisitor* (Say), and *Nemorilla pyste* Wlk.

Tortrix pallorana

Hosts and Distribution

The occurrence of *T. pallorana* as a pest of young pines, although not known before in Ontario, is not new, since McDaniel (1936) reported it causing severe damage to new growth of white, red, Scots and jack pines in plantations in Michigan, in some cases with 95 per cent of the growth killed or deformed. Other workers have reported this insect feeding on cherry, verbena. and *Silphium* (Forbes, 1923), alfalfa (Dean, 1928, Smith *et al.*, 1943, and Snow and McClellan, 1951), roses (Schott, 1925), and strawberry (Smith, 1941). During the present study, larvae were found feeding on white sweet clover, alfalfa, yellow goat's beard, bladder campion, goldenrod, dandelion, Scots pine, and white pine. Feeding on coniferous hosts is restricted to the new shoots during late May and early June. Forbes (1923) lists the distribution as Massachusetts to Illinois, Missouri, and Texas, and Snow and McClellan (1951) record its presence in Utah.

Life History

The life history was determined entirely from field observations, with laboratory rearing being used only for parasite recovery. *T. pallorana* has two generations each year, with adults appearing in late June and again in August. The larvae of the second generation overwinter in silken hibernacula in the leaves of their host plants.

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Summer Generation

Egg

The eggs are deposited on the upper sides of the leaves of alfalfa and white sweet clover during the latter half of June. They appear as light-green shingled masses, similar in shape and size to those of *T. alleniana*. They change to a deep yellow as they mature, and hatch in approximately 10 to 12 days.

Larva

The newly hatched larvae disperse rapidly in the same manner as *T. alleniana*, and the early feeding is also restricted to the upper epidermis of young leaves. As the larvae grow older, they tie several leaves together and feed on all of the tissues. In the case of white sweet clover and alfalfa, they often feed on the flowers as well. The mature larva reaches a length of 25 mm., and the body is pale green or yellowish-green throughout.

Pupa

Pupation occurs within the folded leaves in early August, and the adults emerge in about two weeks. The pupa is 12 to 15 mm. in length, dark brown above and bright yellow below, with orange spiracles.

Adult

The adults appear during the latter part of August, and the main flight period last approximately one week, although scattered moths may be found over a much longer period.

Overwintering Generation

Egg

The eggs of this generation are laid on the short, first-year growth of alfalfa and white sweet clover.

Larva

The newly hatched larvae do not disperse widely in the fall, since the low growth on which the eggs are deposited is protected from the wind by the higher surrounding plants. Feeding begins between the halves of a single folded leaf, and is restricted to the upper epidermis. Hibernacula are spun within the folded leaves, and the larvae overwinter in the second or third instar.

Spring feeding begins early in May on the foliage of the herbaceous perennial weeds. Again, as was the case with *T. alleniana*, some of the larvae feeding on hosts other than alfalfa or white sweet clover may move up on young pines, spruce, and other shrubs and trees during the last two instars.

Pupa

Pupation takes place within the feeding sheath in June, and the adults emerge in about two weeks.

Adults

The flight period of the adults in late June is similar to that described for late August.

Parasitism

All collections for parasite recovery were made in one plantation at Colborne, Ontario. The infestation in this plantation had dropped noticeably since first detected four years previously, but parasitism was light. Larval mortality reached 13 per cent, and the following parasites were recovered: *Glypta simplicipes* Cress., *Glypta rufofasciata* Cress., *Campoplex atridens* Tow., *Bracon politriventris* (Cush.), *Prolixophaga plumbea* (Ald.), *Phytodietus vulgaris* Cress. Pupal mortality reached 1.8 per cent with the following species recovered: *Campoplex atridens* Tow., *Itoplectis conquisitor* (Say), and *Clinocentrus* sp.

Archips rosaceana

Craighead (1950) stated that "the larva . . . is a general feeder on deciduous trees and shrubs, particularly those of the family Rosaceae." In Ontario, the larvae feed on white sweet clover, yellow goat's beard, apple, and Scots pine. This species is found from Nova Scotia to British Columbia and throughout most of the United States (Craighead, 1950), and has been recorded from the island of Guam in the Pacific Ocean (Vandenburg, 1926).

The life history of this insect is well known, having been described as it occurs on forest trees (Craighead, 1950) and on apple (Greenwood, 1942, Venables, 1924). There are two generations each year, and the winter is passed as a small larva in a tightly woven case spun under bark scales or between leaves. The moths from the overwintering generation emerge in June or July, and the moths of the summer generation emerge in late July or August. During the present study this species occurred as single or scattered larvae among collections of larger numbers of *T. alleniana* and *T. pallorana*. The mature larva is similar in size and shape to that of *T. pallorana*, but is easily separated from the latter species by the shiny black head capsule and prothoracic shield.

Sparganothis sulfureana

This familiar species has been recorded on the following hosts: apple, celery, corn, cranberry, red and white clovers, buttercup, strawberry, blue and white vervains, horseweed, burdock, honey locust, willow, pitch and white pines (Beckwith, 1938), on larch, pine, and hawthorn (Raizenne, 1952), and on Scots pine during the present study. It is distributed from Mississippi, Florida, Colorado, Utah, and Washington northwards (Beckwith, 1938).

The life history as it occurs on cranberry in New Jersey has been published in detail by Beckwith (1938), and observations made by the author suggest that it is essentially the same in Ontario, although it was not found in numbers large enough to carry out a detailed study. There are two generations per year, with timing and distribution of stages similar to those of *T. pallorana* and *A. rosaceana*. The larvae are similar in general appearance to those of *T. alleniana*, with the same dark green abdomen, but the head capsule and prothoracic shield are tan yellow and lack dark markings. The average length of mature larvae is about 16 mm.

Sparganothis unifasciana

References to this insect in the literature are brief, and since it was found only in small numbers during this study (never more than 7 per cent of the tortricid population) very little information can be added to our present knowledge at this time. The known hosts are: ash (Raizenne, 1952), white sweet clover, cinquefoil, choke cherry, and Scots pine. Observations suggest that the life history is similar to that of *S. sulfureana*. The larvae are similar to those of *T. pallorana*, but when mature they may be separated by the presence of a tan-yellow head capsule and prothoracic shield, and dark-brown thoracic legs. The average length is 16 mm.

Field Key to the Tortricid Larvae

A.	Abdomen light-green to greenish-yellow	B
A_1	Abdomen light-green below, dark-green above	D
B.	Head capsule and prothoracic shield same colour as body, (light green)	*T. pallorana*
B_1	Head capsule and prothoracic shield not same colour as body	C
C.	Head capsule and prothoracic shield tan coloured	*S. unifasciana*
C_1	Head capsule and prothoracic shield black	*A. rosaceana*
D.	Dark brown to black markings on head and prothoracic shield	*T. alleniana*
D_1	No dark markings on head and prothoracic shield	*S. sulfureana*

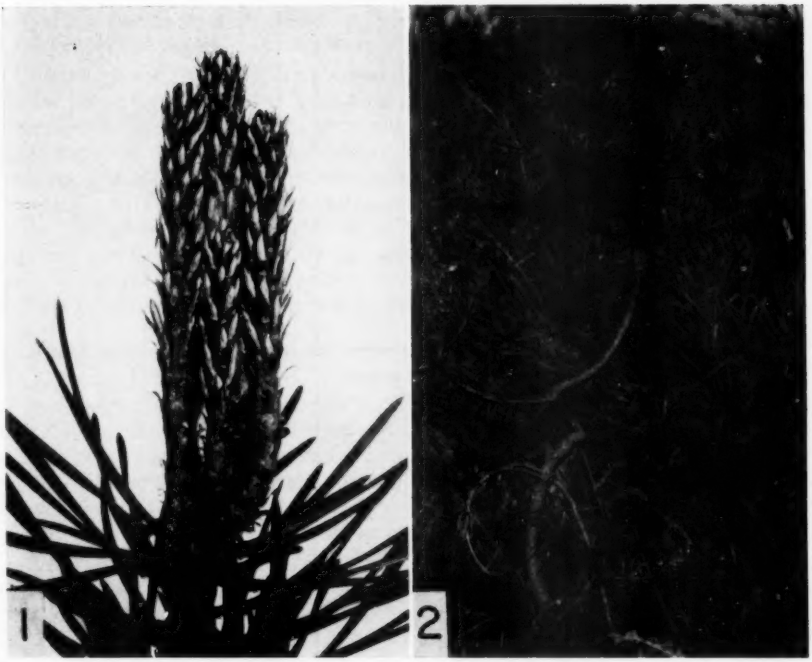

Fig. 1. Shoots of Scots pine tied together by larvae of *T. alleniana*. The larvae are concealed within the shoot cluster.

Fig. 2. A 6-year-old Scots pine, approximately 4 feet in height, showing the typical malformed growth resulting from the feeding of tortricid larvae.

Habits of Tortricid Larvae in Relation to Conifer Injury

Damage to Host

The injury to coniferous hosts by all the tortricids described in this paper is similar. The insects attack the new shoots of the pines after elongation has taken place but before the lateral members have spread away from the central member of the shoot cluster. The young needles are about 6 mm. long at this time. The larvae tie the shoots together (Fig. 1), and feed on the stems and new needles. Some of the shoots may be completely destroyed but others, being injured on only one side, will continue to grow and deformed trees result (Fig. 2). There appears to be only a very short period of time when the shoots of pine are suitable food for these insects. In some plantations and parts of plantations where the trees were growing rapidly, the larvae fed for only a few days and left the trees before appreciable damage occurred. On slower growing trees, however, feeding continued for about two weeks and pupation took place on the trees.

Table 1 shows the preference of *T. pallorana* for the terminal shoots of Scots pine up to 10 inches in height, and for the lateral shoots of larger trees to 32 inches in height. Only rarely were larvae found on shoots over 36 inches from the ground. This behaviour is typical of all five tortricids on both Scots and white pines. The spring growth of pines begins at the top and extends

TABLE I
Coniferous Host Relationships

Av. height of trees	% trees infested	% infested trees with terminal shoot clusters injured	Av. No. larvae per terminal shoot cluster	% infested trees with lateral shoot clusters injured	Av. height of injured lateral shoots	Av. no larvae per lateral shoot cluster	Av. distance to nearest primary host plant
Tortrix pallorana on Scots pine							
10″	65	86	–	60	9″	–	3.7″
17″	25	28	1	83	13″	.6	9″
32″	4	18	1	86	16″	.8	9″
Tortrix alleniana on White spruce							
35″	46	0	0	100	12″	1	8″

gradually downward, and, therefore, the terminals are in the required feeding condition several days before the laterals.

Although the tortricids are commonly found on white spruce, serious injury to this tree species has never been reported. The reason for this is evident in Table 1, which shows that the terminal shoots are not attacked, and since the lateral shoots are much more abundant on white spruce than they are on the pines, the loss of one to three shoots per tree has negligible effects on the growth and form. In extremely heavy infestations, of course, this might not be true. Unlike the pines, the spring growth of white spruce begins at the base of the tree, and the terminal shoots are the last to shed their brown husks. In most cases, larval feeding was complete, and pupation well advanced, before the terminal shoots were in suitable feeding condition.

Movements of larvae and the effects of ground-cover composition and succession.

Although detailed information concerning the movements of larvae could not be accumulated in this short-term study, Table 1 indicates that the average distance from injured trees to the nearest herbaceous hosts varied from 3.7 to 9 inches. The greatest observed distance was about 20 inches. It is therefore probably safe to assume that larvae do not, as a rule, travel more than about a foot during the movement from herbaceous plants to trees.

Early in the study it was felt that there might be a definite stage in old field succession that would encourage attack by these insects. Observations proved, however, that the overall successional movements in the fields had little or no effect, since a new succession begins in the furrows as soon as the trees are planted, and if it is assumed that most larvae do not travel more than about a foot between hosts, practically all tree injury will result from insects originating on herbaceous plants in the furrows. This is further substantiated by the fact that on many plantations herbaceous weeds are found only in the furrows, with the spaces between furrows populated by pure grass communities.

The plant succession that takes place in the furrows is typical in that annual weeds are followed by perennial weeds, and they in turn are followed by grasses. It is during the perennial weed stage, two to four years after planting, that the insects are liable to be most abundant, and the trees most susceptible to injury.

TABLE II

Effects of ground-cover composition* on degree of infestation of Scots pine by *Tortrix alleniana*, Ayton Tract, Lake Huron District, Ont.

Ground cover species (excluding grasses)	Block No. 1 2% trees injured		Block No. 2 38% trees injured	
	Av. Tally	Frequency	Av. Tally	Frequency
Alfalfa	96	86	4.4	12
White sweet clover	–	–	1.4	6
Potentilla	88	98	40	84
Bladder campion	–	–	29	56
Goldenrod	–	–	11	40
Yellow goat's beard	–	–	0.2	4

TABLE III

Effects of ground-cover composition on degree of infestation of Scots pine by *Tortrix pallorana*, Colborne, Ontario

Ground cover species (exclusive of grasses)	BLOCK NO. 1 4% trees injured		BLOCK NO. 2 26% trees injured	
	Av. Tally	Frequency	Av. Tally	Frequency
White sweet clover	49	88	1	6
Bladder campion	10	30	20	56
Yellow goat's beard	9	56	7	36
Goldenrod	6	30	12	6

*Ground-cover composition was determined by the Chain Transect Method (Wilde, 1955). A 100 foot tape was laid along the edge of the furrow and the plants whose horizontal projections touched the chain were recorded. The length of the transect sample in each case was 500 feet. Tally refers to the average number of specimens of certain species per 100 foot tape. Frequency is the number of 10 foot lengths in which a species occurs in relation to the total number of 10 foot lengths surveyed, expressed on a percentage basis.

It is not until the trees have passed the point where injury can be critical that the grasses gain dominance in the furrows.

It has been mentioned earlier that the larvae tend to remain on certain herbaceous hosts for their complete cycle, but that some of the larvae from other hosts will move to trees. It might be expected, therefore, that differences in the composition of the herbaceous vegetation would have definite effects on the degree of infestation of the trees. Two adjacent blocks of Scots pine in the Lake Huron District of southern Ontario illustrate this point (Table 2). On Block No. 1, where alfalfa is abundant and widely distributed, there has been little movement to the trees, whereas on Block No. 2, where alfalfa is comparatively rare, the trees are heavily infested. Two other adjacent blocks of trees infested with *T. pallorana* at Colborne, Ontario, also illustrate this, but in this case tree injury follows the distribution and abundance of white sweet clover (Table 3).

Discussion

The life histories of the five tortricids discussed here are essentially similar, except that *T. alleniana* has only one generation per year while the other species have two. All species are general feeders, but *T. alleniana* and *T. pallorana* seem to favour white sweet clover and alfalfa for oviposition. Severe damage to young pine may result when the larvae feeding on herbaceous hosts, other than white sweet clover and alfalfa, move to the trees and attack the new shoots in late May or in June.

The density and distribution of white sweet clover and alfalfa bear a direct relationship to the intensity of tree infestation; when these herbs are abundant and widely distributed very few trees are infested, but when they appear only as scattered individuals, the degree of tree injury increases. The composition of the ground cover in the furrows has more effect on intensity of tree infestation than the general ground-cover composition of the fields, since the larvae do not seem to travel more than an average of about 1 foot in search of a new host.

Great difficulty has been experienced in controlling *T. pallorana* in seed alfalfa fields (Snow and McClellan, 1951), and it is probable that the same difficulties might arise in attempts to control any of these tortricids on trees. Observations made during this study suggest that in some cases these insects might be

controlled most effectively in the egg stage. Since oviposition is restricted to alfalfa and white sweet clover, and since in plantations suffering the greatest tree injury these legumes occur as widely scattered individuals, it is possible that if these plants were removed and destroyed after the eggs are laid but before they have hatched, effective control might result.

It is probably safe to predict that these insects will become increasingly more troublesome in the future in Southern Ontario. With the increase in Christmas tree growing and tree planting for watershed improvement better quality farmlands with a relatively more luxuriant ground cover are being planted with trees each year. Although there has been a slight indication that these insects go through cycles of abundance lasting for possibly 5 years, parasitism and disease were not found to be high even in the older populations dealt with in this study, and there is a possibility that populations may be maintained at a level capable of causing tree injury for indefinite periods.

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A Temperature Gradient Apparatus for Small Insects

By W. R. Henson[1]

Abstract

An apparatus which provides a temperature gradient within a small enclosed space is described. Provision is made for control of absolute humidity within the apparatus so that the same temperature gradient may be used with a variety of humidity gradients. The system of temperature measurement and recording and the operating characteristics of the machine are described.

Introduction

In order to facilitate the study of physical reactions of small insects, a circular temperature gradient has been built. Previously reported apparatus of this sort (2) has been much too large for use with small insects and has been limited in the variety of gradients which could be established. In addition, the confounding of insects' response to gradient temperature and the inevitable concomitant gradient in humidity has made the aggregation of insects within temperature gradients very difficult to interpret (3). Indeed, it has been suggested that some insects do not have a temperature preferendum as such (2).

In the design of the present apparatus, two objects were held in mind: first to provide variety of gradients which could be controlled and monitored within close limits and secondly, to provide means of investigating the confounding of temperature and evaporation or humidity responses of insects. Some preliminary results have been published elsewhere (4).

Construction

A working drawing of the gradient apparatus is presented in Figure 1. A plate of electrolytic copper 1/4″ thick was cut to a circle 6″ in diameter. Copper tubing 1/4″ od. was bent to the circumference of the plate and soldered to it with the ends of the tube projecting at an angle of 30° from each other. A 1/2″ hole was drilled with a square end drill 1/16″ into the centre of the bottom of the plate and 1/2″ od. copper tube fitted and soldered. A 1/4″ copper tube was fitted through a hole cut in the 1/2″ tube as shown in the diagram.

The copper plate and associated tubing was mounted on a stand made from 6″ od. acrylic tubing cut in the sides to accept rubber tubing water leads and multiple connectors for the thermocouple circuits. Copper-constantan thermocouples made from 24 ga. glass insulated duplex wire were mounted on the outside of the 1/2″ centre drain, in 1/16″ holes drilled 3/16″ into the bottom of the plate at 1/4″ intervals along one radius, and to the outside of both ends of the 1/4″ circumferential tube. The leads from these thermocouples were soldered into 2, 14 terminal, (silver plug) multiple connectors. These connectors were mounted on the wall of the acrylic tubing base. All copper leads were mounted in one connector and all constantan leads in the other.

A space over the upper surface of the plate was enclosed in an acrylic plastic chamber. The sides of the chamber were cut from 6″ od. acrylic tubing and the top from 1/4″ sheet. Some care was taken with the fit of these parts so that minimum air leakage would be allowed. Access to the chamber was provided by cutting a 1/4″ slot in the lid along one radius and closure of the slot was provided by means of a 1/16″ thick slide, key-beveled into a 1/2″ x 1/16″ groove in the top of the lid. This slide was drilled with a 1/4″ hole through which access could be had to any part of the chamber by sliding the hole to the appropriate place in the radial slot and rotating the whole lid to the desired

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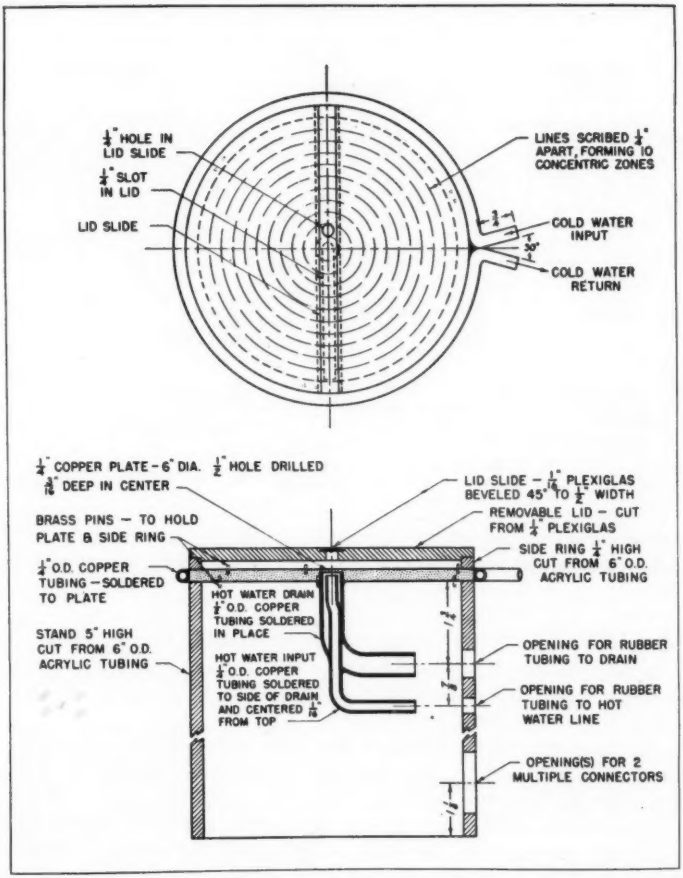
¼" HOLE IN LID SLIDE
¼" SLOT IN LID
LID SLIDE
LINES SCRIBED ¼" APART, FORMING 10 CONCENTRIC ZONES
COLD WATER INPUT
30°
COLD WATER RETURN
¼" COPPER PLATE – 6" DIA. ½" HOLE DRILLED
3/16" DEEP IN CENTER
BRASS PINS – TO HOLD PLATE & SIDE RING
¼" O.D. COPPER TUBING – SOLDERED TO PLATE
STAND 5" HIGH CUT FROM 6" O.D. ACRYLIC TUBING
HOT WATER DRAIN ¼" O.D. COPPER TUBING SOLDERED IN PLACE
HOT WATER INPUT ¼" O.D. COPPER TUBING SOLDERED TO SIDE OF DRAIN AND CENTERED 1/16" FROM TOP
LID SLIDE – 1/16" PLEXIGLAS BEVELED 45° TO ½" WIDTH
REMOVABLE LID – CUT FROM ¼" PLEXIGLAS
SIDE RING ¼" HIGH CUT FROM 6" O.D. ACRYLIC TUBING
OPENING FOR RUBBER TUBING TO DRAIN
OPENING FOR RUBBER TUBING TO HOT WATER LINE
OPENING(S) FOR 2 MULTIPLE CONNECTORS

Fig. 1. Plan and cross section of the circular temperature gradient apparatus.

position. Brass pins were used to secure the chamber to the plate and the plate to its stand.

Temperature Control

The edge of the copper plate is cooled by water circulated from a refrigerated bath. The temperature of this bath can be maintained at any level from ambient temperature to -10°C. when brine is used. The flow rate of the cooling water is held at a level where inflow and outflow temperatures are not more than 1.5 centigrade degrees different. At this level, a satisfactory uniformity in the temperature of the plate border inside the chamber is maintained. The cold brine bath is controlled by a mercury-in-glass thermostat operating a normally open relay which acts as a switch for a compressor. The compressor is a standard self-starting type working with "Freon 12" and supplying an evaporator coil in the brine bath.

The centre of the gradient is heated by water circulated by pump from a hot bath. The water is led in through the ¼" copper tube and out through the

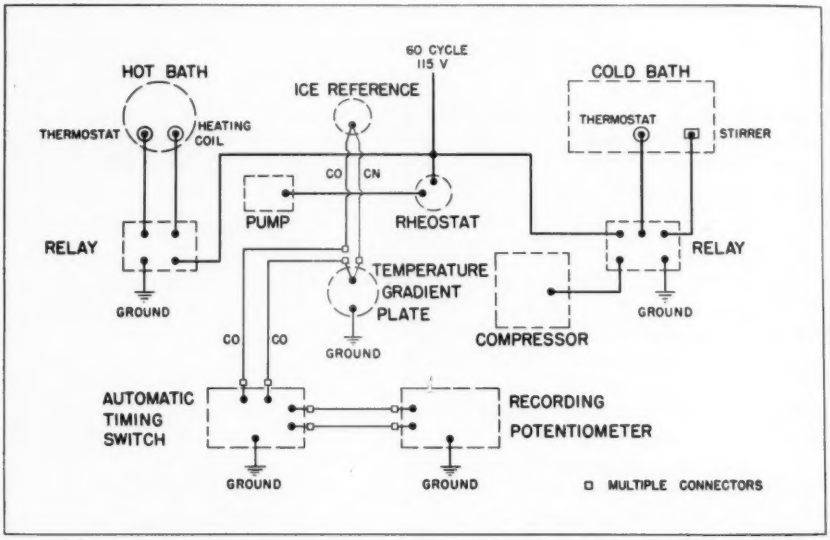

Fig. 2. Schematic diagram of temperature gradient with its control and monitoring systems.

surrounding 1/2″ tube in the centre of the bottom of the gradient. The bath may be operated at any temperature above the ambient and it is controlled by a mercury-in-glass thermostat operating a normally closed relay which acts as a switch for a 1,000 watt heater.

By changing the temperatures of the two baths and by changing the rate of circulation of the heating and cooling water, it is possible to provide any temperature gradient on the surface of the plate with the centre of the plate at a temperature above ambient and below the boiling point of water and the edge of the plate any temperature between ambient and the freezing point of brine. For preliminary tests, it is usual to hold the centre of the plate just above the highest temperature the insects can tolerate without convulsions and the edge of the plate just below the temperature which immobilizes the insects. For more detailed work, the gradient is expanded so that the range of temperature presented to the insects includes only the more critical parts of the original gradient.

Temperature Measurement and Recording

The measurement of plate temperatures is accomplished by means of thermocouples built into the plate. The leads from these thermocouples are taken off through multiple connectors and the copper side run directly to the programming equipment. The constantan leads are connected directly to a series of 14 reference junctions mounted in a Dewar flask. These reference junctions are operated at the temperature of melting ice and the copper leads of the reference junctions are led off to the programming equipment.

A split-cam actuated, double pole, multiple throw switch driven by a synchronous motor is used to program the signals from the thermocouple circuits into an automatic recording potentiometer calibrated to read directly in centigrade degrees. The switching equipment is operated on a cycle of six minutes and it switches both copper leads of each circuit, one at a time, into the poten-

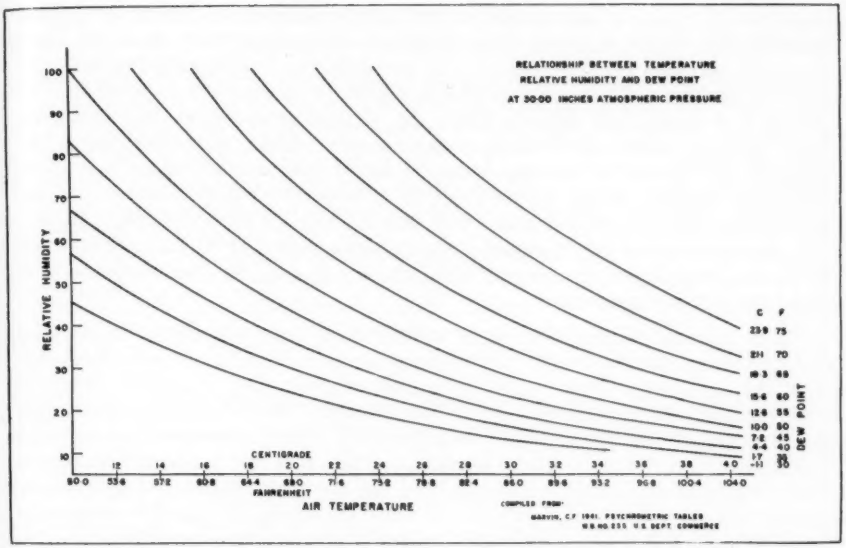

Fig. 3. The relation between air temperature, relative humidity and dew point.

tiometer. Each circuit is switched in for 4% of the six-minute cycle and a grounded circuit which connects all parts of the machine to a common ground and at the same time shorts out the potentiometer is switched in for the unoccupied part of the switching cycle.

By these means, a repeating measurement of all parts of the gradient is recorded with a time check. A schematic diagram of the thermocouple circuits and general arrangement of the various other components of the machine is presented in Figure 2.

Control of Absolute Humidity

Air from a compressed air supply is fed through a porous stone into water contained in a Dewar flask. After being passed through the water, the air is led through a flow gauge to an acrylic plastic fitting making a tight jam fit in the 1/4" hole bored in the top slide of the reaction chamber. Air at an absolute humidity corresponding to a dew point equal to the Dewar flask water temperature is led into the centre of the reaction chamber. Flow rates of about 30-40 cc/min. are used. The air leaves the chamber between the plate and the sides. By adjusting the temperature of the water in the Dewar flask, air of almost any desired absolute humidity may be obtained. At the very low rates of air flow used, the air takes up the temperature of the plate surface with little or no detectable lag. Relative humidity gradients at various levels are thus established as concomitants to the temperature gradients. The choice of gradient to be used is made with reference to a chart extracted from standard psychrometric tables. The essential features of this chart are illustrated in Figure 3.

Operation of the Apparatus

With various combinations of bath temperatures, the temperatures recorded by the built-in thermocouples were compared with maps of surface temperature

made by the use of a butt-welded thermocouple adapted to surface temperature measurement. The variation in temperature at equal distances from the centre along the various radii was found never to exceed ±.5 centigrade degrees. The variation between surface temperature and plate temperature was found never to exceed 0.25 centigrade degrees when the surface temperature was taken at a point directly above the built-in thermocouple. Thus, the temperature of a point on the surface of the plate may be found with a maximum error of 0.75 centigrade degrees simply by finding the distance from the centre of the plate and reading the temperature taken with the appropriate thermocouple. In practice, the accuracy of measurement is much better than 0.75°C. because maximum errors are found with the steepest gradients and in use, the machine is never set to secure extreme gradients.

The amount of variation to be expected in the temperature of the plate surface during operation may be estimated from an examination of a long series of switching cycles. For testing purposes, 45 switching cycles in succession were run without any change in machine settings. The variance of the temperatures recorded for each circuit varied inversely with the temperature recorded. This is doubtless the result of the superior regulation of the hot bath temperature. When standard deviations were calculated for the most variant and least variant circuit, it was found that, for runs of three switching cycles the temperature could be expected to remain within ±0.862°C in the most variable part of the plate whereas in the least variable of the plate, the temperature could be expected to remain within ±0.237°C. These deviations are calculated on the basis of 18 min. runs. In practice, a much closer estimate of plate temperature may be obtained by a direct reading of the chart record. Indeed, the degree of control within the machine results in plate temperatures which are constant within the limits of the temperature measurement.

The temperature of the air within the inclosed chamber has never been found to differ from that of the underlying copper surface by more than 0.25 degrees. By measurements of the position of the ring of condensed moisture in gradients where the temperature falls below the dew point of the air supplied, the accuracy of the control of humidity can be checked. In no case has it been found to be worse than ±2.0% R.H. at the dew point.

After insects are placed in the reaction chamber, their subsequent movements are recorded on a form which contains a plan of the apparatus. In general, two types of observation are used. In the first, a track of a single insect is drawn on the record sheet with time checks placed on the track: the number of time checks is varied in accord with the speed at which the insect moves. In the second type of record, a number of insects at stated times is recorded on the chart. The two types of record supplement each other and in most series of experiments, both types are used. The records are filed with the appropriate trace from the potentiometer from which temperature measurements may be taken directly. Preliminary abstracting of the records consists in the conversation of position data of insects in the apparatus to temperature at the place of observation.

Acknowledgments

Many of the basic ideas incorporated in this apparatus are the result of association with W. G. Wellington over a number of years. Details of design were discussed with W. E. Reifsnyder. W. E. Waters and D. G. Mott assisted in the construction work.

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A Radiographic Technique to Identify Healthy, Parasitized, and Diseased Sawfly Prepupae Within Cocoons[1]

By C. S. Holling

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Many entomological problems require the identification and observation of insects without disturbing their surroundings. Such problems are usually concerned with insects within host or pupal coverings and radiography is a method well suited to their solution. The technique is a special type of radiography in which soft X-rays (wave length longer than about 0.25A), passing through an object of low density, produce a shadow image on fine-grain film in contact with the object.

Radiography has been used principally in identifying and observing insects in seeds. Fenton and Waite (1), for example, were able to differentiate between living and dead larvae of the pink boll-worm in cotton seeds, and Milner *et al.* (3, 4) to identify a variety of insects and their life history stages in wheat, corn, rice, cow peas, and beans. With the exception of the work of Fisher and Tasker (2) who were able to follow the stage and condition of wood-boring insects within wood, other uses of this method in studying insects have been little explored.

The present use of a radiographic technique was developed during studies of the reactions of small-mammal predators to healthy, parasitized, and diseased sawfly prepupae within cocoons. For these studies, it was necessary to obtain supplies of cocoons that could be categorized as healthy, parasitized, or diseased without opening them. This problem was first solved by using a special X-ray machine designed for grain inspection. However, such machines, because of their expense and restricted function, are uncommon. It thus became of advantage to develop a technique using more readily available diagnostic medical X-ray equipment.

The machine available was a "Keleket" X-ray machine with a "Machlet Dynamex" X-ray tube having a rotating anode. Since insects are transparent to ordinary X-rays, the machine was operated at the lowest possible voltage, i.e. 20 kv. The radiation thus produced has a sufficiently low penetrating power to cast a shadow image of the insects on X-ray film. This type of radiation is readily absorbed and scattered, and cocoon and film holders were therefore

1Contribution No. 402, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

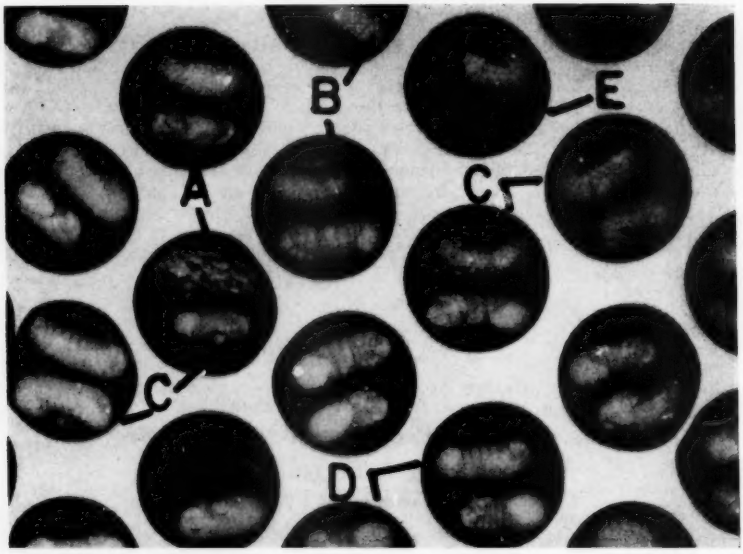

Fig. 1. Microradiograph of *N. sertifer* cocoons showing cocoons containing: (A) Chalcid parasites *Dahlbominus fuscipennis* (Zett.); (B) mature larvae or pupae of the parasite *Exenterus canadensis* Prov.; (C) young parasites of *E. canadensis*; (D) healthy prepupae; and (E) prepupa attacked by fungus. x2.

designed so that a minimum of absorbing material lay between the X-ray source and the film. Each holder contained 250 holes, ½ in. in diameter, drilled through a 9 x 11 in. sheet of ¼ in. lucite. A removable top and fixed bottom of 1/16 in. lucite kept the cocoons in position within the holes. Before radiographs were taken, the sliding top was removed and the holder was placed over a sheet of film in an envelope made from thin black photographic paper. The 1/16 in. lucite and paper between the cocoons and the film did not noticeably affect the clarity of the negatives. After the exposure, the sliding top was replaced so that cocoons would remain in order for later sorting.

A series of test exposures was made at 20 kv. and various amperages and times, using Ansco "Superay B" X-ray film. The clearest radiographs were obtained with exposures of 13 secs. at 75 ma. A portion of a radiograph of a number of *Neodiprion sertifer* (Geoff.) cocoons is shown in Fig. 1. By numbering each radiograph and tray, each cocoon was identified for later segregation. With practice, even cocoons containing very small parasite larvae could be identified. As a check on the accuracy of the method, 200 cocoons were classified from the appropriate radiograph and then opened for positive identification. Agreement was complete.

This method also proved feasible for categorizing cocoons containing healthy, parasitized, and diseased prepupae of other sawfly species—*Neodiprion lecontei* Fitch, *N. pratti banksianae* Roh., and *N. swainei* Midd. The simplicity and accuracy of the method suggest many applications. For example, the development of both host and parasite within cocoons could be accurately observed by periodic radiographs. Where greater precision is needed, existing modifications

of medical radiographic techniques, such as stereoscopic X-ray, might well be adopted.

Acknowledgments

I wish to thank Dr. G. H. Algie, Radiologist, Plummer Memorial Hospital, Sault Ste. Marie, Ontario, for his invaluable help in developing the method and in providing X-ray facilities. The interest and suggestions of Dr. R. M. Belyea, are also gratefully acknowledged.

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An Apparatus for Rapid Indoor Collection of Adult Flies

By GEORGE F. MALLISON, EDWARD R. WILLIAMS AND CHARLES S. RICHARDS[1]

A portable suction-type fly-collecting apparatus has been developed and used extensively in connection with diarrheal disease studies in the Phoenix, Arizona, area. It was designed to facilitate rapid collection of domestic flies from interiors of inhabited dwellings. Conventional or special bait traps (Coffey 1948, Anon. 1952, Schoof 1952) would cause abnormal attraction of flies from extramural sources and create possible nuisances. Many sampled buildings were without electrical power to operate suction-type collecting equipment and use of cone or sweep nets (Maier and Dow 1949) was not practical because of the possibility of damage to household furnishings.

The collecting device consists of a portable vacuum cleaner (Model T-12 Porta-Vac[2]) equipped with a shoulder strap and transparent plexiglass[3] wand bulged at the distal end to accommodate the collecting containers (figure 1). The containers for catching and holding the flies are transparent clearsite polystyrene tubes[4], two inches in length by one and a quarter inches in diameter, threaded for screw-top lids. To prepare the tubes prior to use, a ⅞ inch diameter hole is made in the bottom of each tube and a tightly fitting disc of 14-mesh steel screen wire is forced into the bottom of the tube to cover the hole and retain the flies but at the same time this allows free passage through the tube.

The device was operated in the field from a pickup truck on which a small, battery-started, 110-volt gasoline-motor generator was mounted to supply power. In operation, the truck was parked close to the dwelling to be sampled, the

1From the Communicable Disease Center, Public Health Service, U.S. Department of Health, Education, and Welfare, Phoenix, Arizona.
2Westinghouse Electric Corporation, Pittsburgh 22, Pennsylvania.
3Rohm & Haas Company, Phildelphia, Pennsylvania.
4Celluplastic Corporation, Newark 5, New Jersey.
NOTE: Use of trade names is for identification purposes only and does not constitute endorsement of the product by the U.S. Public Health Service.

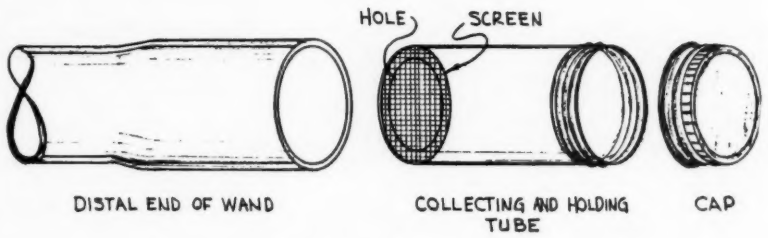

FIG. 1 SKETCH OF THE DISTAL END OF A SUBSTITUTE VACUUM-CLEANER WAND WITH FLY COLLECTING AND HOLDING TUBE.

motor-generator was started, and the portable vacuum cleaner connected with an extension cord and carried into the house. After adult flies were located, the vacuum cleaner was turned on and a collecting tube without lid was inserted into the end of the wand. Air flowing into the wand through the collecting tube pulled flies into the tube when it was moved near them and the flow of air prevented their escape. When a desired number of flies were collected in a tube, the lid was replaced, and the tube then served as a holding container. The bottom was sometimes sealed with masking tape to keep out extraneous matter.

The source of electricity on the truck enabled collections in dwellings without electric service, and simplified the public relations necessary to enter others. The transparent tubes and wand offered minimum disturbance to resting flies. The tubes are relatively soft and did not damage furniture or glass when light contact was made.

The apparatus was originally assembled for making indoor collections of flies for subsequent bacteriological examination for diarrheal disease organisms. For this purpose, the tubes and lids were sterilized prior to each use. Successful isolations of *Shigella* organisms have been made repeatedly from fly pools collected with the device. The same apparatus might be used for collecting samples of flies for other purposes, or for collecting other adult diptera.

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Note on a Method of Artificially Sustaining Larvae of the Wheat Stem Sawfly, *Cephus cinctus* Nort. (Hymenoptera: Cephidae)[1]

By R. KASTING[2] AND A. J. MCGINNIS[3]
Science Service Laboratory, Lethbridge, Alberta

The larva of the wheat stem sawfly, *Cephus cinctus* Nort. feeds entirely within a single host stem and is structurally adapted to this environment (Holmes 1954). Consequently an artificial rearing technique should provide a nutritionally adequate diet in a physical environment which will satisfy the structural needs of the insect. This note describes attempts to rear larvae of the wheat stem sawfly under artificial conditions.

The larvae used were collected on August 9 from a field of Thatcher wheat. Their weights varied from 2 to 25 mg.; the larger larvae were near the end of their feeding period.

The four diets shown in Table I were tested in attempts to maintain the larvae. Diet 1 was a modification of one found satisfactory for rearing the blow fly *Phormia regina* (Meig.) (McGinnis *et al.*, 1956). The protein content of

TABLE I
Composition of diets supplied to wheat stem sawfly larvae

Constituent	Diet			
	1	2	3	4
	percentages			
Vitamin-free casein	29.4	5.5	5.5	–
Yeast extract	2.9	0.5	–	–
Cellulose powder	1.0	27.3	27.8	33.3
Wheat juice	–	–	66.7	–
Water	66.7	66.7	–	66.7
	mg./gm.			
Anhydrous lanolin	1.0	0.3	–	–
NaCl	0.6	0.6	–	–
$CaCl_2$	0.013	0.013	–	–
KCl	0.013	0.013	–	–
$NaHCO_3$	0.013	0.013	–	–
$NaH_2PO_4.H_2O$	0.44	0.44	–	–
K_2HPO_4	0.51	0.51	–	–

diet 2 was comparable to that of wheat stems. In diet 3 juice pressed from stems of Thatcher wheat was substituted for yeast extract, lanolin, minerals, and water. Diet 4 which consisted of powdered cellulose and water served as a control.

Preliminary tests of different types of containers were conducted with diet 1. Test tubes, small bore glass tubing, and grooved plastic trays were unsatisfactory because the medium gelled, many of the larvae were damaged during daily transfers, and others stuck to the container walls. The longest survival period, seven days, was obtained in test tubes. Larvae placed on diet 1 in petri plates lived only three to four days.

1Contribution No. 369, Chemistry Division, and No. 3660, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
2Officer-in-Charge, Chemistry Section.
3Associate Entomologist, Crop Insect Section.

Drinking straws were the most satisfactory of the containers tested. After the diets were packed into the straws by tamping with a glass rod, the ends of the straws were plugged with damp cotton. A small door was cut in the central part of the straw, one larva was inserted, and the opening was sealed with cellulose tape. The containers were kept upright at room temperature in a water saturated atmosphere. The best survival was obtained when the larvae were transferred to freshly prepared straws every 24 or 48 hours. The larvae lived an average of 14 days under these conditions. They tunnelled either upwards or downwards as much as 12 cm. in 24 hours. A frass-like residue was often found at the point of insertion. Some of the straws were cut and grooved in succeeding experiments in which other diets and more mature larvae were used. Head capsules and cocoons were sometimes found within the straws. All these observations suggest that the physical environment was adequate to allow investigation of the nutritional requirements of this insect.

The daily weights and survival periods of larvae maintained on the four diets in drinking straws were compared. None of the diets were satisfactory but some larvae on diets 1 and 2 showed temporary weight increases and survived about two weeks. Diet 3 was least satisfactory as the larvae lived for shorter periods and did not increase in weight. No explanation is offered for the low survival on this diet which contained natural host material. The larvae lost weight on diet 4 but some were still alive after 25 days. The long survival on the cellulose-water diet cannot be accounted for at present. It is possible that either the larvae on diet 4 were more mature which allowed them to live longer or that the casein-containing diets were detrimental.

The weight increases of the larvae on diets 1 and 2 indicate that they ingested the artificial media. Further evidence for ingestion was obtained in a separate experiment in which larvae were exposed for seven days to the cellulose-water diet containing C^{14}-glucose. A radioautogram was prepared from a chromatogram of a larval extract. The residue was subjected to acid hydrolysis and to fractionation on an ion exchange column. Both procedures showed that radioactivity was present in compounds other than glucose, which indicates that glucose had been ingested and metabolized.

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